water
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volume 5 no 1 July 2002

Special Issue

Proceeding of the 5th Symposium on Sustainable Water Resources Development

Arbaminch
23 - 24, July 2001

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contents

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is a biannual published by the Arbaminch Water Technology Institute. Basically the journal entertains and / or supposed to entertain different approaches the major issues and problems in the water sector; it is a forum which gives a great deal of access to various professional views and outlooks to be reflected and discussed.

It also makes possible for the rich experience and wisdom of outstanding personalities in water engineering to reach and be utilized by those concerned. Most of all, **water** encourages and gives much more opportunity to young engineers to introduce their works and eventually to cultivate the tradition using a journal.

Finally, with the ultimate goal of bringing about basic changes and development in all aspects of the country's water sector, **water** calls for articles to the of the purpose.

editorial board

guide to authors

Manuscripts in water science and technology are considered for publication. Manuscripts must be in English. Scientific and research papers, review papers, technical notes, short reports, letters to the editors are well accepted in **water.** Papers already published, or in press elsewhere, will not be accepted. The total length of a manuscript including figures tables and references should not exceed 7000 word equivalents (10 pages). The original and three copies should be submitted.

The manuscript must be addressed to: Research and Publication Coordination Service, Arbaminch Water Technology Institute, P.O. Box 21, Arbaminch Ethiopia. All copies should be carefully checked and error free.

Authors requiring the return of the manuscript or original material should make their request known as soon as possible, as they will normally be discarded one month after publication.

The first page should contain the full title of the manuscript, the name(s) of the author(s) including addresses and the institution(s) in which the research was carried out. If more than one author is involved, the author to whom all correspondence will be addressed should be indicated by an asterisk. The first page should also contain the ABSTRACT.

A desirable, though not strictly prescribed plan, for the organization of a research paper is to start with an INTRODUCTION giving a description of the problem and its relation to other works in the same field. The objective(s) of the investigation should also be stated in this section. Abbreviations (e.g. BAP, 6-Benzlyaminopurine; GA3, gibberellic acid 3; etc.) should be put under the INTRODUCTION in a separate paragraph. The remaining sections can then cover MATERIALS AND METHODS, RESULTS AND DISCUSSION or CONCLUSIONS. Then follows ACKNOWLEDGMENTS, if any, and the last item would be a list of REFERENCES.

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water will be distributed for free up to the end of 1999.

We would be very grateful should you send us names and addresses of individuals or institutions, if any, who are working in the water sector and interested in the contents of our journal. We very much like to send them free copies.

Dear Readers/Contributors

The knowledge of water is one of the major prerequisites for alleviating many problems in relation to food self-sufficiency and security, natural resources management and sustainable development.

This proceeding includes papers presented by researchers, engineers, experts, managers, etc. on the 5th *symposium on "Sustainable Water Resources Development" held 23 and 24 of July 2001at AWTI.*

In this symposium 19 papers has been presented. The symposium reviewed papers on Water Supply and Sanitation, Irrigation, Water & Environment and Hydrology &Water Resources.

The editorial board would like to thank all authors for their contributions. It also invites all concerned experts to contribute and publish on the research journal 'WATER' or to the symposium proceeding.

The Editors
July 2002

Fifth Symposium on 'Sustainable Water Resources Development'

23 - 24, July 2001
Arbaminch

Welcoming Address

by Dr.-Ing Seleshi Bekele
Chairman,
Symposium organizing commitee

Distinguished Guests,
Dear Participants,
Ladies and Gentlemen,

On behalf of Arbaminch Water Technology Institute, the organizing committee and that of my own, I would like to express my heartfelt pleasure in welcoming you to this 5th Symposium organized at our Institute on the Theme of "Sustainable Water Resources Development".

Distinguished Guests,
Dear Participants,
Ladies and Gentlemen,

Sustainable and judicious development of the water resource of Ethiopia demand among a number of things, good scientific and technical capabilities, which help to curb number of problems related to the available water resources potential. One of the methods through which such capabilities can be built is through research and development and promoting and disseminating the out puts obtained through such endeavors.

In our country, it is not deniable that certain studies and research, though very limited, in the sector have been and are conducted in various organizations and institutions, with practically insignificant mechanisms to disseminate the results and information among the concerned ones.

Thus, the Arbaminch Water Technology Institute, as it has been the Institute exclusively devoted to training and research in the water sector, had taken the initiative five years ago to organize the first symposium and now reached the fifth one in the series. It is our firim believe that the participants of the symposium were benefited and the objective of the symposiums conducted in the past have been fulfilled. This fifth symposium has been organized with similar purpose of providing a forum of deliberation and exchange of ideas on research findings, study results and other experiences on topics of sustainable water resources development.

Since the announcement of this fifth symposium at the end of May 2001, which is a short duration, we have received a total of 32 papers. Out of these papers we have selected 18 papers, and all theses papers are expected to be presented in these two days, being subdivided in four sub-themes.

Ladies and gentlemen, allow me once again to say welcome to the fifth symposium of Sustainable Water Resources Development.

With this brief remark, I have the honour to invite Ato Bogale G/Mariam, the Acting Dean of the Institute for an opening speech.

Opening Address

Bogale G/Mariam, Acting Dean

Dear colleagues,
Invited guests,

On behalf of the Institute community, I am honored to welcome to this Fifth Symposium on Sustainable Water Resources Development. As we constantly conduct this important event every year, it offers an opportunity for professionals to come together to consult on new approaches, share knowledge and interesting experiences, explore problems and investigate solutions to research and development oriented activities to help society meet its scientific, technological, environmental, economic and social challenges.

This symposium is a forum to address the issues of rationalized use and protection of water resources against pollution and degradation, along with the stabilization of the environmental situation, which are of crucial importance for development.

This scientific program reflects the concern and contribution of AWTI to the development of national cooperation in water resources development. It also expresses our willingness, desire, and commitment to work in collaboration with others and to expand partnerships with other educational and research institutions, and government and the private sector, building upon each others' strength and focusing on what each can do best.

Our aspiration is to make AWTI as a model of excellence. We strive to continuously improve in the areas of learing, discovery, and engagement with society (encompassing service and outreach). Aiming to be less than the best is unacceptable.

There is a deep sense of pride that continues to grow among all of us who care so much for this Yearly symposium as it gains momentum every year. I am pleased to say our efforts are working.

Dear participants,

We represent the ideas of sharing and partnership by recognizing and respecting your professional papers and presentations, which are essential contributions to strengthen our programs. The combined talents and commitments from many areas will make improvements that will have a lasting positive impact on countries development.

I believe that the presentations, comments, questions and answers, and issues that will raise during common sessions and break time help us to develop shared vision of our future. I wish all participants a successful and lively exchange of ideas and pleasant stay in Arba Minch.

My thanks for all of you who work so hard for this symposium. We look forward to working with all of you as we make this annual symposium even better and more desirable in the years ahead.

And I now declare the Symposium is open.

Thank you.

The Status of the Water Sector in Ethiopia and the Improvement of Water Supplies in Oromiya Region Project A German Input

Gerd Foerch, Prof. Dr.-Ing. RODECO Consulting and GTZ

Summary

The German Government played a major role in supporting the development of the water sector in Ethiopia. Since the late seventies of last century she sponsored various projects in co-operation with the National Water Commission and later the Ministry of Water Resources and regional Water Bureaux. The establishment of the Faculty of Technology at Addis Ababa University and the support of Arba Minch Water Technology Institute were the most prominent ones, besides water supply projects for several urban centres and regional states. At present, the German Government is rendering support to the Regional States of Oromiya and Tigray as well as to AWTI. This support is most probably slimming down in future, since the governments are negotiating on focal areas for development co-operation, where water is only an option for a future set-up. The water sector is not playing a major role in Ethio-German development co-operation at present, which could be attributed to the effects of the Ethiopian boarder conflict with Eritrea. However, the input for the Regional State of Oromiya, which was primarily concentrating on rural water supplies, was also guided towards the water sector reform in Oromiya, thus also contributing to the overall development of the sector in Ethiopia.

Introduction

Ethiopia has ample water resources, which are under-utilised in certain places and endangered at others. Furthermore, rainfall is not evenly distributed over the country with maximum rain depths in the humid western highlands and almost no rain in the arid eastern lowlands. The rainfall pattern is not homogenous with distinct different climatic characteristics and large variability of rain distribution over the seasons and regions. Orographic conditions and the location of the inner tropical convergence zone (ITCZ) are the general influencing factors, furthermore, El Ninjo and El Ninja factors are decisive for the occurrence of dry and wet spells as well.[1]

Ethiopia has a rapidly growing population with growth-rates between 2.6% [2] and more than 3 % per annum, with areas exceeding even 4% especially in the south, e.g. with Arba Minch. Because of the low level of production and productivity[3] and the wide spread poverty, a severe and still accelerating overuse of natural resources can be observed: the defined forest cover is now close to 2% of the land area.[4] Bush land once covered the region between Sodo and Arba Minch; within the last 5 years only this region was changed almost completely into farmland. This development indicates that once untouched soil is no exposed to extensive and traditional farming, with consequences on soil erosion and sedimentation of lakes and reservoirs.

The socio-economic situation in Ethiopia is characterised by a declining per capita income and a dwindling gross national product. Consequently, Ethiopia is heavily and increasingly depending on the financial assistance of international donors. A large portion of the Government revenues needed for covering public spending is depending on international loans and multi as well as bi-lateral projects. At the moment, the since last December newly agreed international loans for supporting infra-structural development are by far exceeding 1 Billion US $.

The Water Sector

The water sector as well is heavily depending on technical and financial input from international donors as well as non-governmental organisations. However, the Ethiopian Government tried over the last years to develop the legal and institutional framework for better utilisation and protection of the natural resources as well as the available funds. In her endeavour several Governments, like the Dutch, the German, the Japanese and the Swedish supported the Federal Government; and multi-national organisations like World Bank, UNDP, the WSP and the European Commission paid their tribute as well. Some of these achievements are listed below:

- Establishment of a water ministry at federal level
- Development of a federal water resources policy[5]
- Re-organisation of water institutions at regional levels[6]
- Proclamation of a federal water resources management law[7]
- Proclamation of a federal health and sanitation law
- Development of a federal environmental policy
- Establishment of the federal environmental protection agency

And we have to name the interna-

tionally most respected activity, which is

· The development of a concise international policy known as the "Nile Basin Initiative 2002", where the Ethiopian Water Minister is playing a decisive role.

Most of these achievements would have been impossible without the support of bilateral and multi-national assistance.

However, none of these achievements will sustain without the input and involvement of national and regional professionals, government institutions, and private entrepreneurs. The graduates of AWTI, which are known to be well trained, have to play a major role within this context. They have to take over the responsibility for their share of the development of the Ethiopian people, for the development of Ethiopian the water sector.[8]

The Achievements

What are the basic achievements for the change of the water sector so far?

· The water supply sector is slowly opening up for de-central water provision and private sector involvement, as stated e.g. by the Regional State of Oromiya.[9]

· Water provision must be organised near to the consumer and must be based on community management principles considering consumer demands. This demand driven approach for water provision is now accepted as the basic tool. [10]

· Water is finally understood as an economic good, the provision of which must be paid for by the consumer [11] ; the cost coverage principle is e.g. successfully introduced in Oromiya.[12]

· Sanitation is accepted as an individual concept for which the public sector needs to provide certain infrastructure[13]

· Water resources must be assessed, evaluated and managed in order to minimise expropriation and damage, since water resources form the decisive basis for any human development[14]

· Water resources management must be exercised in an integrated manner following holistic approaches on basin and catchment level[15]

· Water use in any sense must be regulated and should follow the "user pays" principle[16]

However, the implementation of such far-reaching principles requires highly skilled professionals and a supportive administrative and political environment, not forgetting the tremendous funds required. Again it should be stressed, that the AWTI graduates are among the most prominent professionals to take up these demanding jobs and obligations.

The major international inputs at present

Where are we now?

· The Dutch Government is supporting the development of the National Water and Sanitation Master Plan as part of the environmental support programme.

· The international donors (WSP and UNDP) are supporting the draft of the Water Sector Development Programme, which is designed for organising international assistance to the sector under one guiding umbrella.

· The World Bank is supporting the 25 Towns Water Supply Project, where capacity building as well as technical measures are developed and implemented.

· The EU is supporting AAWSA to improve water supply and sanitation coverage in Addis Ababa.

· The German, Swedish and Finnish Governments are supporting regional water supply and sanitation efforts.

· The EU is supporting watershed management projects as well as erosion and sedimentation monitoring as part of the food security measures.

· Many NGOs are supporting local water supply and sanitation projects as well as watershed management and irrigation projects.

It can be stated that there are quite a number of activities, out which the majority is financed and executed by international donors and experts. However, we should not deny the efforts of federal and regional governments who still invest into the water supply sector an operate most of the facilities. The present water coverage of less than 30% demands for more combined efforts and better co-ordination. A proposal was made by the MoWR to the council of ministers to install a "Water Fund" for accumulating funds for investing into urban water supply systems in future. This measure may help to improve the financial situation, but without the input of ordinary people through their purchasing power (to buy water at cost prises), without professional and commercial water provision, and without appropriate water resources monitoring the difficult situation may not change in the long run.

More input is required from the Ethiopian people and professional institutions.

Where are the inputs of Ethiopian professionals or professional institutions? There are some institutions, like

- Ethiopian Design Enterprise
- Consulting Companies
- Research Institutions
- Contractors and Suppliers

But this input is not enough for a sustaining water supply and water resources sector. These few did not change the water supply coverage over the last years much. These institutions did not produce much substantial professional input except for supporting foreign inputs. There is no Ethiopian investor who spent his money in the water sector at present.

The future German input

Where will the German input go? From the last official consultations between the Ethiopian and the German government it is known, that the German development co-operation and respective contributions shall continue. However, there will be a special focus of activities on three sectors: Skill Development, Management of natural resources for food security, and Development of democratic institutions, good

governance and the like. The water sector is only a focal area for future inputs.[17] The focal areas are understood that all German inputs, financial as well as technical co-operation and integrated experts, are going to be related to these areas agreed upon.

However, existing projects shall not be stopped, and there might be some room for development in future as well.

- The project Assistance to AWTI shall continue as planned: That is to develop the research potential in the water sector in general and at AWTI in particular.

- Support the commercialisation of water provision e.g. in Oromiya Region with selected small municipalities.

- Support the development of water resources management capacity of regional states, like in Oromiya and Tigray.

- Support of natural resource management at various levels with the aim to improve food security, where also water resources may play a role. Watershed management techniques shall be employed.

- Support of "good governance" efforts (democratic institutions, decentralisation, privatisation etc) may also relate to water institutions.

- Support of skill development (professional skills below the level of academic grades, like masons, plumbers etc) shall also benefit the water sector

Conclusions

A symposium like the AWTI Symposia on Sustainable Water Resources Development is an important event for exchanging ideas and to listen to theories, concepts and solutions. It is an important place for young professionals to understand that there education is not over with their graduation. Every day they have to learn something new, since every day they are going to face problems for which they do not have ready made solutions. However, their skills for analysing problems and finding solutions are indispensable. Without the young professionals attending this symposium the water sector in Ethiopia may not develop as necessary and planned.

[1] Forecasts for rainfall amounts and distribution, which are used by the MoWR for reservoir management, are successfully based upon these factors

[2] The latest estimate published by the Central Statistical Office in June 2001 is suggesting a small decline of the growth-rate all over Ethiopia

[3] Ethiopia is rated the last state on earth if it comes to economic development, clearly to be seen with the declining gross national product per capita, which is at present roughly 100 US $ per person and year

[4] The forest cover is reported to be more than 40% at the beginning of last century

[5] MoWR (1999) Water Resources Management Policy

[6] GTZ/RODECO (1999), Reorganisation Study for the Oromiya Water, Minerals and Mines Resources Development Bureau

[7] Federal Government (2000) Water Resources Management Proclamation

[8] It is a disaster for AWTI as well as for the country that most of those young academics, who leave for their PhD-studies abroad, decide to stay outside of Ethiopia, thus depriving their own people from their urgently needed professional inputs

[9] Oromiya State Council (1999), Proclamation for the amendment of executive organs, the UWSS are to be developed into autonomous institutions

[10] WSP (1999) Mpumalanga Statement on Financing Rural Water Supply and Sanitation

[11] Water Resources Management Proclamation

[12] OWMERDB (1999) Management Guidelines for RWSS

[13] GTZ/RODECO (2001) Adulala Pilot Sanitation Report

[14] MoWR (2000) Water Resources Management Proclamation

[15] dto

[16] dto

[17] Minutes of the Government Consultations, June 2001

Studies on Bioremediation of Pulp and Paper Mill Effluent by Sequential Treatment with Microorganisms.

Michael Alraha Mekelle, Tigray P.O.Box 10

Abstract

Bioremediation performance of Heterobasidion annosum ,a white rot fungus,Streptomyces albadumcus, an actinomycetes and Brochothrix sp, a bacterium was evaluated when used individually and sequentially (in tandem) on an effluent taken from Century Pulp and Paper Mill ltd. The maximum biodegradation result were achieved by using the sequence fungi followed by actinomycetes and then by bacteria, each for five days, which resulted in 81.8% reduction in color and 87.65% reduction in COD within 15 days in comparison to 69.44% color and 72% COD reduction by white-rot fungi alone which is empirically justified to have superior performance over any of the individually studied microorganisms in this investigation. This enhanced efficiency was attributable to the improvement in the biodegradability of substrates, through the various metabolic activities contributed by different microorganisms.

Key words: **Bioremediation; Biodegradation; Decolorization; Pulp and Paper Mill effluent; wastewater treatment**

I.Introduction

During recent years pollution of water from industrial wastes (effluents) due to rapid industrialization, has focused considerable attention on the quality of receiving waters (**Modi *et al.*, 1998**). Pulp and paper mills rank third in terms of fresh water withdrawal after metal and chemical industry. It is believed that by the year 2000, the paper industry will become the largest user of water for manufacturing of paper (**Khoshoo, 1986**). It is also estimated that about 250-450 m³ of water is required per ton of paper produced (**Mahajan, 1989**) that consequently generates 200-300m³ as wastewater (**Subahmanyam and Hanumanulu, 1976**).

The pulp and paper mill effluent is highly colored imparting a black/ brown color (**Eaton *et al.*, 1980**) and complex chlorinated organic compounds like chlorolignin, phenolics and dioxins (**Eriksson *et al.*, 1980**) that are known to be toxic to the biological system. *Ipso facto* water pollution and other environmental regulations are beginning to require this industry to systematically reduce the color and contents of its effluent (**Martin and Manzanares, 1993**). Numerous physico-chemical methods have also been used for the treatment of pulp and paper mill effluent (**Eaton *et al.*, 1980**). The problems underlying the physico-chemical treatments are those associated with cost, reliability, voluminous sludge and generation of secondary effluents such as chlorinated organics (**Bajpai and Bajpai, 1997**).

In recent years, there has been a growing interest in the potential use of biotechnological methods to convert or utilize plant residue and industrial wastes of lignocellulose origin (**Hera *et al.*, 1978**). A number of bacteria and actinomycetes have been known to utilize lignin and remove color from effluents (**Amer and Drew, 1980; Kirk, 1971; Eriksson, 1980; Antai and Crawford, 1980**). However, most of the work has been done by the use of white-rot fungi (basidiomycetes) because of their known ability to degrade lignin (**Martin and Manzanares, 1993**) and decolorize the effluent by destroying both the color bodies and chromophoric structure (**Crawford and Crawford, 1980**).

Since there is limited information on the use of sequential treatment, the objective of the present investigation was to evaluate the effect of sequential treatment with different combination of fungi, actinomycetes and bacteria for the removal of color, COD and changes in pH and EC of pulp and paper mill effluent. The advantage of using sequential treatment lies in that each species involved in the sequence will play substantial role in the overall degradation of the effluent, with the inadequacies of one microorganism fulfilled by the abilities of others.

II. Materials and Methods

2.1 Materials

Culture: All the cultures used in this investigation were obtained from microbial collection maintained in the Department of Environmental Sciences, G.B. Pant University, India.

The cultures used were

i. *Heterobasidion annosum*- a white rot fungus

ii. *Brochothrix sp*- Gram positive, non-motile and non-spore former bacteria.

iii. *Streptomyces albadumcus*- Gram positive actinomycetes (spore mass color creamish and spore chain retina)

Chemicals and Glassware: The chemicals and glassware used during the course of this investigation were of analytical grade.

Apparatus: BOD incubator, centrifuge, spectrophotometer, hot air oven, laminar flow, EC meter,orbital gyratory shaker,vertical autoclave, torsion balance, mantle heater, refrigerator, Quebec counter, light microscope, aquarium pump and multi- thermometer were used.

Culture media: Culture media is prepared by the following procedure.

Component	g/l
Yeast extract	5.00
Glucose	10.00
Agar	15.00

Table 2.1 Composition of medium for Heterobasidion annosum

The final volume was made up to 1 litre with distilled water. The pH of the medium was adjusted to5.8. The cultures were maintained at 25°C for 10 days. Strepto-penicillin (2 mg/ml) was added to them to avoid bacterial contamination.

Component	g/l
Starch	10.00
Casein (vitamin free)	00.30
KNO_3	02.00
NaCl	02.00
$K_2H^nO_4$	02.00
$MgSO_4.7H_2O$	00.05
$CaCO_3$	00.02
$FeSO_4.7H_2O$	00.01
Agar	15.00

Table 2.2 Composition of medium for Streptomyces albadurncus

The final volume was made up to 1 litre with distilled water and pH of the medium was maintained between 7.6 - 8.0. The antibiotic cycloheximide was added at a final concentration of 50 mg/ml.

Component	g/l
NH_4Cl	2.00
K_2HPO_4	3.00
NaCl	0.10
$MgSO_4.7H_2O$	0.30
Yeast extract	1.00
Agar	15.00

Table 2.3 Composition of medium for Brochothrix *sp*

The final volume was made up to 1 liter with distilled water and pH of the medium was maintained at 6.5.

Nutrient salt	Amount g/l
$MgSO_4.H_2O$	1.00
KCl	0.50
Yeast extract	1.00g
$Na_2B_4O7.10H_2O$	100.00g
$CuSO_4.5H_2O$	50.00mg
$FeSO_4.7H_2O$	50.00mg
$MnSO_4.4H_2O$	10.00mg
$NH_4MoO_4.4H_2O$	10.00mg
$ZnSO_4.7H_2O$	70.00mg
Thiamine	1.00mg

Table 2.4 Composition of the micronutrient solution

2.2 Methods

Sampling: The effluent samples were collected from the main outlet at discharge point outside the factory boundary. Temperature of the samples was determined at the spot. Immediately after collection, the effluent was brought to laboratory and stored in a refrigerator at 4°C till used for analysis.

Maintenance of Culture and Preparation of inocula: The stock cultures were subcultured on their respective media and inocula were prepared by the following procedure.

Fungal inocula (pellets):

Fungal pellets were prepared using modified method of **Pallerla *et al.* (1995).** Four mycelial disks taken from the actively grown zone of the culture on agar plate and inoculated in a 500 ml shake flask containing 150 ml of yeast-glucose broth at pH 4.8. Three 2.4 cm diameter glass beads were added to the flask in order to obtain uniform suspension of mycelial particles. The flask was continuously agitated at 200 rpm for 24 h. After 24 h, the supernatant broth was decanted and a final suspension of about 50 ml per flask was transferred to a second 500 ml shake flask containing 150 ml broth. The flasks were oxygenated once a day for 3 min. All these operations were carried out under aseptic condition. After five days, pellets of variable diameters were obtained. The pellets were washed with saline solution (0.85% NaCl). Because of their highly variable size, it was not possible to use pellets by count method. Thus, in this experiment, the technique used by **Pallerla *et al.* (1995)** was modified and 5 ml of the inoculum (v/v) was used per 150 ml effluent for treatment.

Bacterial and actinomycetes inocula:

Fifty ml bacteria and actinomycetes broth were prepared in triplicate in 100 ml Erlenmeyer flask. The prepared broth was inoculated with respective inoculum. Bacterial culture was kept on a rotary shaker at 25°C and 150 rpm for 2 days while that of actinomycetes were shaken at 30°C for 4 days. Thereafter, 1 ml of the broth was taken from each flask and subjected to serial dilutions up to 10^{-7}. 0.1 ml of actinomycetes and 0.5 ml for bacteria, inoculum was taken from 10^{-7} dilution and pour plated in a petri plate containing respective media. Bacterial cultures were incubated at 25°C for 3 days while actinomycetes cultures were incubated at 30°C for 5 days in a BOD incubator. Finally, colony count was performed using Quebec counter and the size of inoculum to be taken for treatment was determined. In each step the purity of the culture was checked by Gram's staining technique.

Thereafter, the colony forming unit (CFU) was calculated to equalize the size of inoculum to be taken in each treatment, the ratio of bacteria to actinomycetes was calculated to be 1:3. Thus, in each 250 ml flask containing 150 ml effluent, 3 ml of actinomycetes and 1 ml of bacteria inoculum were taken which gives 24×10^4 CFU per flask.

In all investigation work, basic nutrients were supplied at the rate of 1% glucose and 0.175% ammonium nitrate, according to **Modi et al.,(1977) and Kumar et al., (1998)** as the best and optimum carbon and nitrogen sources, respectively. Micronutrient was prepared and supplied (10 ml/l) after modifying the suggestion of **Martin and Manzanares (1993)** by adding 1 mg/l thiamine.

Treatment:

1.With individual microorganisms.

Fungi

One hundred and fifty ml of effluent samples were transferred into 2 sets of triplicate 250 ml Erlenmeyer flasks. Glucose 1% (w/v), ammonium nitrate 0.175% (w/v) and micronutrient solution 1% (v/v) were added in each flask. Three flasks of the first set were now inoculated with *Heterobasidion annosum* and the rest of three flasks of the second set were taken as control against the three flasks. All the flasks were inoculated on rotary shaker at 25°C and 150 rpm for five days. Various physico-chemical parameters were recorded after 0, 1, 3 and 5 days of start of inoculation. At the sixth day nutrients were supplied for each flask and pH of the flasks was adjusted to 5.8. Shaking was continued up to 10 days. Again color, COD, pH and EC measurements were carried out at the 7th and 10th days of the experiment. Finally

nutrients were supplied for each flask followed by pH adjustment towards 5.8. Shaking was continued up to 15th day. At the end of all the physico-chemical parameters were measured.

Actinomycetes

One hundred and fifty ml of effluent samples were transferred into 2 sets of triplicate 250 ml Erlenmeyer flasks. Nutrients were supplied to each flask. Two flasks of the first set were inoculated with *Streptomyces albadumcus* and the rest of two flasks of the second set were taken as control against first two flasks. All the flasks were kept on a rotary shaker at 25°C and 150 rpm for five days. Physico-chemical parameters were taken. At the beginning of the sixth day, nutrients were added in each flask and the pH of the effluent was adjusted towards 7.6. Shaking continued for 5 days. Physico-chemical parameters were again measured at the end of the 7th and 10th day of treatment. At the start of 11th day, nutrients were added in each flask and pH, in the mean time was adjusted to 7.6. For five more days, shaking continued which will bring the total treatment to the end of fifteen days. Eventually, color, COD, pH and EC were measured.

Bacteria

Treatment with bacteria follows the same procedure with that of actinomycetes except in case of bacteria inoculum was *Brochothrix* sp. and the pH of the effluent was adjusted to 6.5 at the end of each five day treatment.

2. Sequential treatment:

Three sets of quadruplicate 250 ml sterilized Erlenmeyer flasks were filled with 150 ml of sample effluent. In all the flasks glucose, ammonium nitrate and micronutrient solution were added . The first 8 flasks of set 1 and set 2 treatments were inoculated with fungi while the rest of the flasks were taken as a control . All the 12 flasks were then shaken at 150 rpm and 25°C for 5 days. COD, color, pH and EC were measured at zero and fifth day of experiment. After removing the fungal mycelia by centrifuging at 6000 rpm for 30 min, in one set of flasks the pH of the same effluent was adjusted to 7.6 using 0.5 N NaOH and these were inoculated with actinomycetes cultures. In the other set of flasks, the pH was adjusted to 6.5 using 0.5 N NaOH and inoculated with bacteria. Thereafter, the flasks were kept on rotary shaker at 25°C and 150 rpm for 30 min. Color, COD, pH and EC were measured as described. Subsequently, the flasks, which were previously inoculated with fungi followed by actinomycetes, were inoculated with bacteria were then inoculated with actinomycetes after adjusting the pH to 7.6 using 0.5 N NaOH. Finally the flasks were shaken at 150 rpm and 25°C for five days. Again color, COD, pH and EC were measured. In each flask, 1% glucose, 0.175% ammonium nitrate and 1% micronutrient solutions were added before each inoculation.

Analytical methods:

Decolorization assay: The color of the effluent was determined according to the CPPA standard method CPPA, (1974).

Chemical oxygen demand (COD): COD of the sample was measured according to the method given by Moore et al.,(1949).

Measurement of pH: pH of the effluent was measured using Systronics pH meter after calibrating with pH buffer of 4,7 and 9.2.

Measurement of electrical conductivity (EC): EC of the effluent was measured using a pocket type digital EC meter (Hanna Instrument Co.) calibrated at 25°C. The reading was taken in international system of units (SI), i.e., milli Siemens per meter (mS/m).

1 mS/m = 10 μ mhos/cm

III. Results and Discussion

Effect of individual microorganism on the physico-chemical parameters of pulp and paper mill effluent:

In general, all the three microorganisms tested viz., *H. annosum* (white-rot fungus), *S. albadumcus* (actinomycetes) and *Brochothrix* sp. (bacterium) have shown considerable decrease in color, COD and pH. The increase in EC was also observed. The highest degree of decolorization and COD reduction, however, was achieved by *H. annosum*, 69.24% and 72.08%, respectively, followed by *Streptomyces albadumcus* which caused reduction of 46.47% color and 50.22% COD at the end of fifteen days treatment. *Brochothrix* sp. exhibited the lowest performance in removal of color but with a better degree of COD reduction in comparison to *S. albadumcus*.

Reduction in pH seems to accompany reduction in color and COD. The lowest pH record was always, as a matter of fact, correlated with the highest degradation of organic matter. The result, thus, support the finding of many researchers (**Livernoche *et al*., 1983; Garg *et al*., 1999**). On the other hand, data observed in this experiment seems to induce a doubt whether highest EC is always the function of highest mineralization because Fig 3.4 clearly shows that treatment with *Brochothrix* sp. resulted in maximum increase in EC 15.18% when compared with 8.14% and 7.16% increase in *H. annosum* and *B. albadumcus*, respectively. Basically EC is a numerical expression of the ability of an aqueous solution to carry out electric current. This ability depends on the presence of ions, their total concentration, mobility, valence and temperature of measurement. Solution of most inorganic acids, bases and salts are relatively good conductors. Conversely, molecules of organic compounds that do not dissociate in aqueous solution conduct a current very poorly, if at all. Therefore, increase in EC of the effluent usually shows the probable formation of inorganic compounds as the result of mineralization action of microorganisms. **Nobuyuki *et al* (1995)** also observed rapid decrease in pH and increase in conductivity followed by a steady state when humic acid is degraded by ozone, indicating the formation of polar substances, chiefly low molecular mass organic acids.

Interestingly, one can observe that about 85% of the total reduction in color and COD were obtained at the end of 5th day treatment. These values were found to be approximately 63% at 3rd day of treatment. Higher value of the order of 94% seems the maximum attainable peak within a reasonably short period of time i.e., 7 days; from seven day onward only slight decrease is observed (Fig. 3.1- 3.3).The indigenous microflora also contributed an average of 8.07% reduction in COD and 7.72% reduction in colour (Table 3.7).It is after this figure the net reduction is calculated.

Table-3.1: Gross change in COD

Species	Day 0	Day 5	Day 7	Day 10	Day 15
H.annosum	9500 (100)	6338.78 (66.83)	7194.25 (75.78)	7358.74 (77.12)	7640.40 (80.43)
S.albadumcus	9500 (100)	4755.70 (50.00)	3182.14 (34.55)	3426.85 (39.85)	5931.89 (62.44)
Brochothrix sp.	9500 (100)	446 5.00 (47)	4942.88 (52.03)	5247.30 (56.29)	5644.21 (59.33)
FAB	5500 (100)	4000.00 (72.73)		4530.00 (84.00)	5004.067 (90.98)
FBA	5500 (100)	4000.00 (72.73)	-	4510.00 (82.00)	4720.00 (85.83)

Table-3.2: Gross change in Colour

Species	Day 0	Day 5	Day 7	Day 10	Day 15
H.annosum	3598.40 (100)	2933.34 (85.80)	2598.77 (72.16)	2695.01 (74.79)	2774.88 (77.10)
S.albadumcus	3598.40 (100)	1660.34 (46.14)	1811.11 (50.33)	1970.63 (54.20)	1309.89 (40.67)
Brochothrix sp.	3598.40 (100)	1243.23 (34.55)	1419.50 (39.78)	1561.88 (43.40)	1562.26 (43.45)
FAB	2410.13 (100)	1420.23 (66.37)	-	1734.85 (81.06)	1683.61 (87.08)
FBA	2410.13 (100)	1420.45 (66.35)	-	1585.93 (74.00)	1649.10 (76.94)

Table-3.3: Gross change in EC

Species	Day 0	Day 5	Day 7	Day 10	Day 15
H.annosum	4.49 (100)	0.13 (2.73)	0.16 (3.35)	0.40 (8.19)	0.40 (8.14)
S.albadumcus	4.49 (100)	0.15 (3.19)	0.25 (5.29)	0.31 (6.44)	0.35 (7.16)
Brochothrix sp.	4.49 (100)	0.18 (3.87)	0.28 (5.94)	0.43 (9.07)	0.73 (15.18)
FAB	4.15 (100)	0.21 (4.88)	-	0.48 (10.86)	1.06 (23.50)
FBA	4.15 (100)	0.21 (4.19)	-	0.60 (14.52)	0.96 (21.29)

Table-3.4: Net change in COD

Species	Day 0	Day 5	Day 7	Day 10	Day 15
H.annosum	5500 (100)	4674.78 (61.01)	4734.95 (58.25)	5073.34 (70.01)	4800.82 (72.08)
S.albadumcus	9650 (100)	3455.90 (45.17)	3581.44 (45.20)	3591.00 (45.11)	3560.64 (50.22)
Brochothrix sp.	9500 (100)	5169.20 (33.81)	3493.28 (33.11)	3905.00 (46.47)	3798.33 (49.15)
FAB	5500 (100)	6301.00 (66.28)	-	5353.00 (77.71)	5319.00 (87.65)
FBA	5500 (100)	5010.00 (66.74)	-	5135.00 (72.33)	5235.00 (80.57)

Table-3.5: Net change in Colour

Species	Day 0	Day 5	Day 7	Day 10	Day 15
H.annosum	3598.40 (100)	1611.33 (36.43)	1737.45 (63.43)	1823.42 (66.77)	1872.34 (69.46)
S.albadumcus	3598.40 (100)	1880.63 (31.79)	1456.19 (40.66)	1508.90 (44.20)	1309.89 (46.67)
Brochothrix sp.	3598.40 (100)	663.55 (21.95)	767.73 (26.86)	863.22 (21.28)	972.83 (17.33)
FAB	2410.13 (100)	969.69 (37.39)	-	1157.00 (74.06)	1242.99 (81.80)
FBA	2410.13 (100)	799.69 (51.59)	-	1005.93 (64.10)	1068.75 (70.34)

Table 3.6 Contribution of indigenous microflora

Species	Day 0	Day 5	Day 7	Day 10	Day 15
H.annosum	4.49 (100)	0.13 (2.73)	0.16 (3.35)	0.40 (8.19)	0.40 (8.14)
S.albadumcus	4.49 (100)	0.15 (3.19)	0.25 (5.29)	0.31 (6.44)	0.35 (7.16)
Brochothrix sp.	4.49 (100)	0.18 (3.87)	0.28 (5.94)	0.43 (9.07)	0.73 (15.18)
FAB	4.15 (100)	0.21 (4.88)	-	0.48 (10.86)	1.06 (23.50)
FBA	4.15 (100)	0.21 (4.18)	-	0.60 (14.52)	0.96 (21.29)

Effect of sequential biological treatment:

Though very little work is reported on sequential biological treatment of pollutants, the idea given by **Yin *et al.* (1989c)** and **Timmis and Pieper (1999)** seems adequate enough to substantiate the concept and support the findings of the present study. Results on sequential treatment of pulp and paper mill effluent are given in Table 3.1- 3.6 and Fig 3.5 – 3.7. These results can be compared with the result of the performance of individual microorganisms given in Table 3.1-3.6 and Fig.3.1-3.4.

It is interesting to note that irrespective of the combination made, sequential treatment resulted in greater achievement over any of treatment performed using individual microorganisms. For instance *H. annosum* which has shown 69.44% color and 72.08% COD reduction is still less effective when compared even with the lowest result obtained by combining fungus- bacteria-actinomycetes in tandem. However, the best result was obtained by using fungi-actinomycetes-bacteria sequence which reduced 81.8% color and 87.65% COD load of the effluent.

In this experiment it can be empirically observed that color and COD reductions are positively correlated. Correlation analysis also suggests that decolorization and degradation of chlorolignins (as COD decrease) are metabolically connected, although these processes have different rates **(Bajpai and Bajpai, 1997)**. The highest increase in EC of all the experiments is shown by this combination (23.50%).

In both combinations, more than 85% of the reduction in COD and color is achieved within 5 days of treatment with fungi. This result corroborates with the conclusion made by many researchers **(Livernoche *et al.*, 1983; Davis and Burns, 1989; Paice *et al.*, 1989; Archibald *et al.*, 1990; Mehna *et al.*, 1995; Modi *et al.*, 1999; Garg *et al.*, 1999)** which signifies that white-rot fungi (basidiomycetes) are the best decolorizer and lignin degrader.

The second highest effect was shown by actinomycetes, which accounts for the approximate 10% reduction of the color and COD. Similar with the result obtained by individual treatment, *Brochothrix* sp., has shown

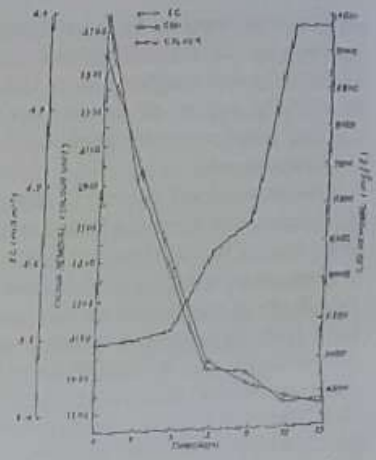

Fig 3.1 Change in color, COD and EC of the effluent treated by H.annosum for 15 days

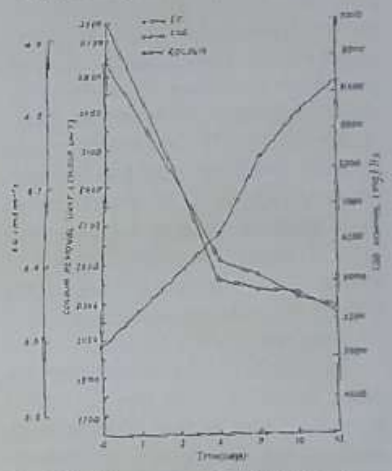

Fig 3.2 Change in color, COD and EC of the effluent treated by S.albadumcus for 15 days

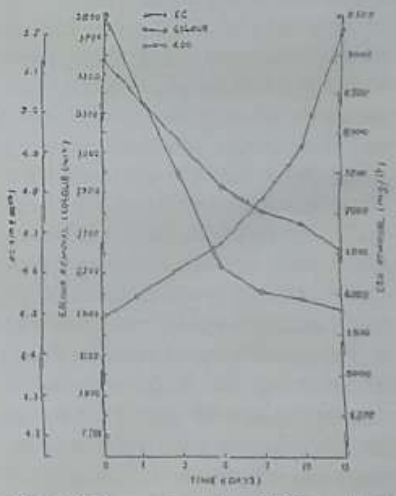

Fig 3.3Change in color, COD and EC of the effluent treated by Brochothrix sp. For 15 days

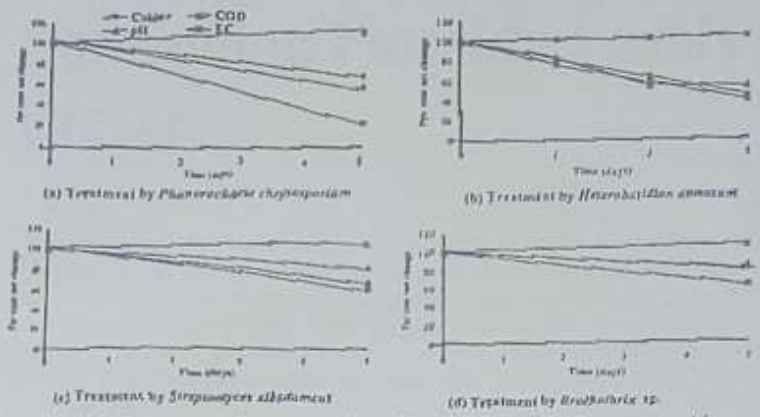

Fig 3.5 Percent net change in color, pH and EC of the effluent treated by

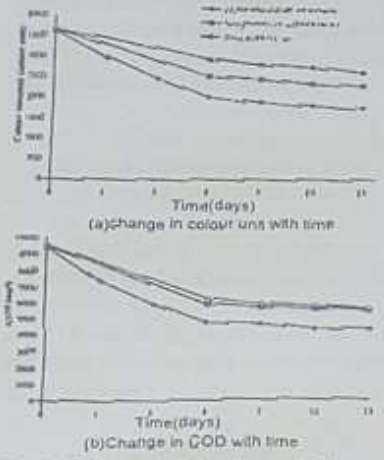

Fig 3.4 Change in(a) color and (b) COD of the effluent after 15 days of incubation with H.annosum , S.albadumcus,and Brochothrix sp

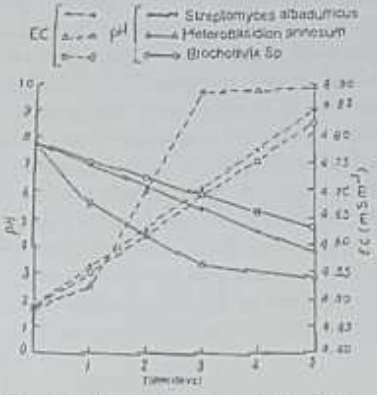

Fig 3.6 Change in EC and pH of the effluent after 5 days of incubation with H.annosum , S.albadumcus,and Brochothrix sp.

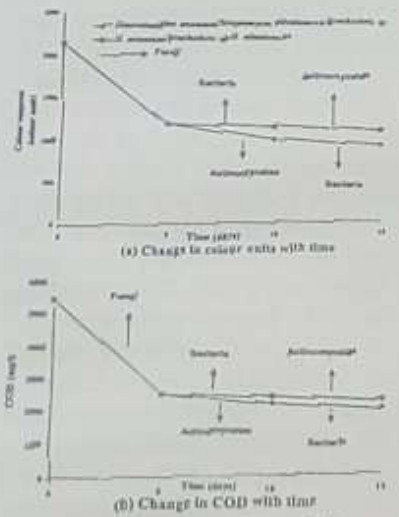

Fig 3.7 Change in(a) color and (b) COD of the effluent after 15 days of incubation with various sequentially-combined microorgani

relatively lesser effect in the sequence. pH change is highly associated with the degree of reduction in COD and color. The lowest pH recorded was 3.3 after treatment with fungi and the highest 5.57 following treatment with bacteria.

IV. Conclusion

From the present investigation it is empirically possible to conclude that the use of sequential biological treatment can enhance substrate biodegradation. This enhanced efficiency could be due to the improvement in the bioavailability of substrates, through various metabolic 'division of labour' contributed by different microorganisms. On the other hand, the use of individual microorganisms have shown inferior result, this may be attributable to the fact that single or very few enzymes produced by single microorganism are not able to mimic the complete biological system to yield better effect on bioremediation. The authors, at this juncture, suggests further studies on screening specialist biocatalysts, creating new metabolic routes and the use of sequential biological treatment along with the physico-chemical treatment methods like precipitation, adsorption on activated carbon, membrane techniques, ultrafiltration etc., for a more efficient bioremediation.

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Controlling Fluoride Levels in Drinking Water

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Abstract

Fluorine, the most electronegative of all elements is physiologically more active than any other elemental ion and therefore, it displays physiological properties of great interest and importance for human health and well being. Fluoride in small doses has remarkable influence on the dental system by inhibiting the dental caries, which in higher doses causes a disturbance of enamel structure information. However, it is known to exert subtle influence (s) on other systems of the body and thereby play an overall paramount role in human health and disease manifestable not only through its deficiencies but also its excess. Interestingly, the margin between its curative and the harmful doses is quite narrow.

Fluoride, if present in excess in groundwater, causes fluorosis. If the fluoride concentration is below 0.5 mg/l or above 1.5 mg/l in drinking water, it is considered harmful. The disease manifests itself through discoloring and mottling of teeth and in an advanced stage damages bones and joints. The damage is medically irreversible.

Excessive levels of fluoride are not uncommon for water supplies in a number of countries. . In villages and towns of the Ethiopian rift valley, the fluoride level of drinking water collected from wells ranges from 1.5 mg F/l to 36 mg F/l.

In such situations the need for appropriate control measures is important and this brief guide reviews many of the available options. Although reference is made to the requirements of developing countries, various procedures used worldwide to remove fluoride from small water supplies are reviewed. An outline of each method is described for treating supplies where the level of fluoride continuously and significantly exceeds the levels recommended by WHO.

A wide range of treatment options are noted and evaluated. It is not possible here to specify the most appropriate method for use in certain situations. This is because local conditions, including the quality of the water supply, the availability of local skills, cost and many other factors must be considered. Nevertheless, this review refers to the types of factors that may need to be considered when selecting a method for defluoridation. An evaluation is given of both the more expensive and sophisticated methods as well as the less expensive simple and limited techniques. Methods are presented in two categories: (i) somewhat limited-application systems and (ii) commonly used and well tried systems.

1. Introduction

There are a number of natural minerals which contain the element fluorine, and some of these contribute to the level of fluoride ion (F) found in water sources used for drinking. Fluoride normally exists in low concentrations in many waters . Surface waters generally do not contain more than about 0.3 mg F per litre. Where fluoride-rich volcanic rocks are common, levels greater than 1000 mg F per litre have been reported in ground waters. Deep- well water sources are the most common type of groundwater which can contain rather elevated levels of fluoride . Worldwide, there are numerous water supplies which contain elevated levels of fluoride. In villages and towns of Ethiopian rift valley, the fluoride level of drinking water collected from wells ranges from 1.5 mg F/l to 36 mg F/l. where fluoridation of water supplies is practised, careful control is generally exercised to maintain the fluoride concentration very near 1 mg F per litre . The exact level depends on the local temperature, since this factor governs the volume of water consumed .

Although concentrations up to 1.5mg F per liter can be beneficial,as demonstrated by low dental caries incidence rates, levels in excess of this concentration can cause undesirable effects At levels slightly above 1.5 mg F per liter, mottling of teeth has been reported . At still higher levels teeth may be damaged, even severely; at 3-6 mg F per liter, skeletal fluorosis, due to significant effect on the bone, may be observed. If a concentration of 10mg F per liter is exceeded, the fluorosis, causing crippling, can result.

Because the literature review is also covering the treatment of water in situations pre vailing in developing countries, special considerations are required to this effect. For example, the availability of local skills for plant operators and their training (and re-training) on a regular basis are important requirements.This is particularly important in remote and rural areas. The regular supply of chemicals and various spare parts etc., especially if they are imported, may in some cases be difficult to guarantee . In selecting a control option in a developing country it is paramount that such factors are not over looked.

2. Fluoride control options

If some form of control is considered necessary, one or more of the following options may be applicable: (I) provision of a new or alternative source of water containing acceptable levels of fluoride, (ii) blending of the existing water supply with another containing lower levels of fluoride, (iii) provision of bottled water, (iv) treating the water at the " point of use" such as in a small treatment device attached to the household drinking-water outlet; and (v) treatment of the water at its source. One extreme option for a rural area of a developing country could even be the re-settlement of a

community to an area of acceptable water supply quality, if no other possible options were available. Each of these options is discussed further in the following.

2.1 Provision of a low-fluoride source of water

This option is only possible under certain geological and hydrological circumstances. If to achieve this, a new well supply is deemed necessary, it may prove an option with high initial costs but lasting benefits for the community. One cannot always guarantee the longer term quality and quantity from a new source in a given locality. Pumping water from another suitable source may be possible, but again cost considerations are important, especially if long pipelines are necessary.

2.2 Blending with low-fluoride water

Blending with an adequate alternative source of water can be an appropriate option so long as problems do not result from physical or chemical reactions in the blended waters. Blending with shallow-well water is utilized, and in consequence particular attention must be given here to the use of chlorination equipment. Blending with low-fluoride water was reported have been successfully applied in the USA. This option is of potential usefulness in developing countries since it provides for a simple long-term solution which does not require costly treatment. The only condition is the availability of suitable blending water within reasonable distance and of acceptable quality with regard to fluoride and other constituents.

2.3 Provision of bottled drinking-water

This is a very effective method of control, but as a long-term option it could be very expensive. Except in special circumstances, such a provision is unlikely to be a suitable action in most countries, developed or developing.

2.4 "point-of-use" water treatment

Reverse osmosis and activated alumina "point-of-use" Systems Were installed in households used successfully in some developed countries . Although the level of fluoride can be readily controlled there is a possible danger of the system acting as a growth site for bacteria . The individual capital cost to the householder for a reverse osmosis device may be fairly high, and the careful maintenance and operation of these devices is very important . Recent experiences with various "point-of –use" systems have been recorded. For various reasons such a provision is unlikely to be suitable for situations in many developing countries at the present time. However, it was recently reported in Mexico that a simple and economically viable system exists. It is based on the use of pre-treated bone as an adsorbent to control at the "point-of –use" and excessing fluoride in drinking water .

2.5 Treatment of water supply sources

There exists a wide range of treatment systems which have been used for controlling excessive levels of fluoride in drinking water. Some systems are very expensive; some will only operate with certain types of water quality, and others are in practice rather ineffective in reducing the fluoride concentration to acceptable levels. The procedures involve chemical and physical methods of removal such as precipitation, adsorption, ion exchange and deionization of the fluoride. The following alternative systems exist:

- addition of ferric iron
- lime softening
- use of alum (aluminum sulphate)
- adsorption on activated carbon
- ion exchange resins including zeolite
- use of bone
- electrodialysis
- use of various treatment agents such as magnesium salts, calcium phosphate, bentonites, fuller's earth, diatomaceous earth, silica gel, sodium silicate,sodium aluminate, seprpentine or carbion
- use of defluoron
- use of bauxite
- use of lime and alum (Nalgonda technique)
- use of bone char
- use of synthetic bone
- reverse osmosis systems
- use of activated alumina.

The first eight systems listed have either rather limited application for fluoride removal or are not sufficiently well-tried to tbe recommended universally. Even so, in particulate circumstances, they may be quite effective and may not necessarily be unduly expensive. Before a final decision is made on a system to use, the various options described in this review should be considered. If one of the systems given in sections 3 and 4 below is seriously contemplated, then careful bench-scale, and pilot-scale testing is generally needed. A comprehensive report has been pulished on the use of some systems for developing countries . Various methods are evaluated and costed in this report

3. Limited-application water treatment systems

The more commonly used and well-tried methods will be given detailed consideration in section 4.

3.1 Ferric iron addition

A floc of a ferric fluoride complex is produced using ferric salts. Normally, only minimal fluoride removal is achieved, e.g. 5.0 mg F per litre is reduced to 4.7 mg F per liter, using 85mg ferric salts per litre at pH 7.2 followed by 340 mg lime per litre This normally considered an acceptable system to ouse and only included here for completeness of records.

3.2 lime softening for fluoride removal

Under certain conditions it is possible to remove fluoride as a side reaction to the lime softening of a water containing high levels of magnesium. The process involves co-precipitation of the fluoride with magnesium hydroxide . This is a feasible process only when both hardness and fluoride removal are desired and the water contains sufficient magnesium. Even then it is more effective where the levels of fluoride are moderately low, i.e. be-

tween 3 and 4 mg per litre. A detailed analysis of the process has been published indicating that strict control of pH is necessary . Some hard waters have been reported to have been treated economically where the natural magnesium level was high. This method is linked to the softening process which limits its applicability.

3.3 Use of alum (aluminum sulphate)

Although having a high adsorption capacity for fluoride removal, alum is only suitable for treating certain types of water . In the presence of some cations, its capacity is reduced and this frequently makes the method uneconomical . The method has been demonstrated to be capable of reducing the fluoride level from 7.5 to 0.8 mg per litre after 2 hours at pH 7.2 to 8.4. Its effectiveness has also been examined under different conditions. At the high alum doses used there is a danger in the absence of adequate control, however, that residual aluminum levels may exceed the WHO guideline value for drinking-water of 0.2 mg aluminum per litre, relating to the water's aesthetic quality .When combined with lime the use of alum, as in the Nalgonda technique, has been successful in India .

3.4 Adsorption on activated carbon

Although the fluoride removal efficiency can be high with this process, it is pH dependent . At pH 3, a level of 8 mg fluoride per litre can be readily reduced to 1 mg per litre . However, the method can be costly to operate since the pH of the water needs to be lower initially, and finally it must be raised to make the water suitable for potable purposes. Despite the high efficiency of carbon for fluoride removal, the bauxite and activated alumina systems (see section 4.2 and 4.7) are regarded as considerably superior. Many activated carbons have a very narrow optimal pH range, and also their effectiveness can be reduced by the presence of other substances in the water . Their efficiencies under different conditions have been investigated. Because of high cost and its limitations, this method is unlikely to be of value in developing countries.

3.5 Ion exchange

Research carried out with such systems suggests that the method has limitations, and it can be relatively expensive. One problem is the competition for the ion exchange resin that exists between fluoride and other anions which may be present in the water. Amberlite resin XE-75 has been reported to be quite effective for removing fluorides . Various resins have been tested and a brief account of their usefulness has been published. Economic considerations normally make resins uncompetitive, however. Natural zeolites generally have a small capacity for fluoride removal and this precludes their use as an appropriate treatment option. Because of the cost implication, ion exchange systems in general are unlikely to be of particular value for use in developing countries at the present time.

3.6 Treatment using bone

This can be an effective method for fluoride removal but taste problems have been reported to be associated with the treated water. However, the situation can be improved by specially treating the bone with potassium hydroxide solution . The principle of the method depends on replacing the fluoride ion in the water with the carbonate ion present in bone. After its use, the bone needs to be treated with caustic soda to remove the chemically bound fluoride before the bone can be re-used. Economic factors and the comparative advantages of charred bone (see section 4.4) and synthetic tricalcium phosphate/ hydroxyapatite mixtures have tended to make the use of bone itself less attractive .

3.7 Electro dialysis

This methos is not normally expected to be cost-effective in comparison with other cheaper methods such as bone-char or alumina. A membrane separation/electro dialysis methods been used successfully for brackish water . The different procedures for electrodialysis were recently evaluated . The method is not likely to be appropriate for use in developing countries.

3.8Use of various treatment agents

Various treatment agents are proposed: magnesium salts, calcium phosphate, bentonites, fuller's earth, diatomaceous earth, silica gel, sodium silicate, sodium aluminate, serpentine and carbion (a action exchange resin). Although tests with these agents for removing fluoride have been reported , little is known regarding their general usefulness and applicability, some of these agents required the pH of the water to be adjusted to a low value (less than pH3) to provide effective fluoride removal. Calcium phosphate has recently been reported to be very efficient for fluoride removal. But no information on its practical application is yet available. Even so, in specific case, where there is cheap and availability of a suitable agent, it could be contemplated. However, pilot tests are essential to check out the effectiveness of the agent for the water in question. In general, because there are other more appropriate options available (see section 4) the above-listed treatment agents are unlikely to be of widespread value for use in developing countries.

4 . Commonly used methods of water treatment

The somewhat limited-application water treatment systems are considered in section 3 above. When reviewing the literature world-wide, defluoron, bauxite, lime together with alum (nalgonda technige) bone-char, reverse osmosis, and activated alumina have found their specific application, They show promise for the effective removal of fluoride covering a range of circumstances. These methods are considered in greater detail below. Nevertheless, even with well-tried methods, problems may arise for reasons that include a special type of water quality, the quality of the regents used, water temperatures, and local human skills. Before any treatment of supplies is introduced, adequate bench-scale tests followed by appropriate pilot plan trials for each source of

supply is strongly recommended. This testing is specially recommended for situations in developing countries.

4.1 Defluoron-2 as ion exchange medium

This material has been reported to be successfully used in India . A country where water supplies contain excessive levels of fluoride Deflouron-2 is a cation exchange medium made by sulphonating coal; alum is used to regenerate the material. A *defluoridation* plant capable of treating 5.5 m³ of water per hour per cubic meter of medium has been described. The wash-water treatment, the regeneration process with alum and their aspects of the method have been fully described. Fluoride levels below 1mg F per litre are achievable where the raw water contains 3-10mg F per litre operating and treatment costs of this method have been documented There seems to have been little interest in *this* method outside of India. In relation to other techniques used in India like that of alum and lime (Nalgonda technigue) the use of defluoron-2 has been regarded as cumbersome in operation and regenration it has been reported that skilled operators are needed to obtain effective control with defluoron –2 . This condition severely limits practical usefulness of this method.

4.2Use of bauxite

The use of bauxite is considered superior to that of activated carbon (see section 3.4). It has a narrow optimum pH range, and in this sense it is not as flexible as alumina (see ion 4.7). One study suggested that a pH of less than 3 is needed for reasonable efficiency of fluoride removal . In another report, an excellent removal efficiency of more than 90% fluoride was achieved with a 4-hour Contact time at a pH of 5.5 to 7 with adsorbent does of 25g per litre . At a level of 40mg F per litre, a reduction to 1 mg F per litre was readily achieved . Bauxite is said to also have some other disadvantages in comparison with alumina, such as a lower removal capacity and a higher mechanical wear. However, bauxite normally costs less than alumina. The effectiveness of bauxite and its comparative performance with alumina have been investigated. Other chemical species apparently do not normally interfere with the fluorides removal process using bauxite. Despite some advantages of bauxite, it has been little used. Under certain conditions it might have some applications in developing countries.

4.3 Lime and alum treatment (Nalgonda technique)

The methods known as the Nalgonda technique has been very successfully used in India; it is first described in 1975. The principles of the method and its details are fully documented . The method involved adding in sequence sodium aluminate or lime (usually lime because it is cheaper), and then filter alum . Bleaching powder may be added simultaneously for disinfection. The unit operations involved are flocculation sedimentation and filtration. Fluoride levels can be reduced to 1mg per litre except where the alkalinity of the water is low; if necessary, the alkalinity can be increased by means of lime addition. This method has been successfully used for individual as well as community water supplies in India. Bucket and drum-scale use and pilot scale testing have been documented under a range of conditions . The Nalgonda technique is considered to incur very low cost . The procedure would seem *particularly* appropriate for application in developing countries.

As an example, one plant using this technique where 495mg alum per litre was added, provided treated water averaging 0.7 to 1.2 mg F per litre . The raw water contained an derange of 4.1 to 4.8 mg F per llitre, and its hardness was 284mg $CaCO_3$ per litre, 7.2-8.2 and alkalinity 410-500 mg CaCoc per litre. total of 3173 kg alum was used to treat 6423 m³ water in 143 hours; this corresponded to an average water flow of 45 m³ hour, although the design capacity of the plant was about twice this figure. The sanitation of sludge over a period of 24 hours provided a concentration of 2.6% W/V solids in sludge which was subsequently dried on sand beds . Precise details of costing of plant are available.

4.4 Use of bone-char

Bone-char is ground animal bones which have been charred to remove all organic matter. It is considered better than bone itself, because taste problems of the treated water are minimized . The material has been used successfully to control excessive fluoride. For example, in the United States fluoride levels were lowered from 6.7 to 1.5mg F per litre with 30-50 mesh bone-char. With one plant where 8.5m³ bone-char was used, regeneration of the absorbing material was found to be needed only after 3800 m³ of water had been treated. Back washing followed by caustic soda is used in this pro excess caustic soda is removed by rinsing the bed of bone-char with a considerable volume of raw water .

The use of bone-char has certain drawbacks in comparison to treatment with activated alumina. Arsenic can interfere with the effectiveness of bone-char, since arsenic itself is very readily adsorbed and causes irreversible changes in the structure of the bone-char, ultimately rendering it useless . If significant quantities of arsenic are present, then other methods such as activated alumina should be used . Media loss can occur with bone-char, and this can create problems.

In summary, bone-char has been successfully used, but it has some limitations and nowadays the use of activated alumina is more popular. The use of bone-char could be an appropriate option in some developing countries.

4.5 Use of synthetic bone

This material is made by reacting phosphoric acid with lime to produce tricalcium phosphate hydroxyapatite (synthetic bone). It is reported to be cheaper than bone-char and can be readily produce in the form of coarse granules that are suitable for use . Various tests using this adsorbent have been carried out. Synthetic bone is used and regenerated in a similar way to bone-char . As with bone-char, some media loss occurs but to an even

greater extent. The material has not been widely used, although plants have been rated in the USA . There seems to be little experience with the material in developing countries.

4.6 Reverse Osmosis

This system utilizes a semi-permeable membrane which retains the dissolved solids in the water. It is costly to operate, and the efficiency of the process is both pH and temperature dependent. The process has been reviewed and evaluated. In recent years household systems for " point-of-use" reverse osmosis have been specially evaluated.

The membrane is a critical part of the system. Spiral tubular, hollow-fibre and plate and frame types have been used. Because of the high pressure-drop across the very thin membrane used, the later needs to be extremely well supported. Commercially available membranes are often cellulose- based; nylon is also used. Problems of membrane fouling arise in use, caused commonly by (a) colloidal material and certain dissolved salts and (b) poor control of the raw water. This fouling can lead to concentration polarization and cause a deterioration in product water quality. Cleaning of membranes may be regularly needed, and pretreatment of the raw water may be required. Calcium carbonate scale is controlled by pH adjustment. Some difficulties of reverse osmosis in special circumstances have been examined. A wide range of reverse osmosis systems have evaluated. Many of these are highly efficient; some involve multistage processes A very detailed review of the process has been published. Because of cost, the method is not likely at the present time to be of great value to developing countries.

In summary, although highly efficient, the system is costly to operate, and problems may rise with certain types of water. The system has the advantage that other undesirable ions in addition to fluoride are removed, and this feature could be beneficial in certain situations. New and improved membranes at lower cost are under development in the USA .

4.7 Activated alumina

This system is in developed countries one of the most widely used and favored methods currently available. Many reviews of its use and effectiveness have been published. Activated alumina is a special form of acid-treated alumina. Its affinity for fluoride is very high, i.e. in descending order hydroxide> phosphate>fluoride> sulphite> ferrocyanide> chromate > sulphate > dichromate > nitrite > bromide >chloride > nitrate . A number of bench-scale tests have been carried out. After use the alumina needs to be reactivated. Levels of 10 mg F per liter can readily be reduced to around 1 mg F per litre . Control of optimum pH 5 to 6 is important in the use of alumina ., and carefully operated regeneration procedures are necessary . The fluoride adsorption capacity is not significantly reduced by elevated levels of total dissolved solids, except when sulphate exceeds 10mg per litre. The theory of fluoride removal with alumina was investigated . A pilot study was carried out to test the efficiency of alumina for removing fluoride when arsenic is also present in the water in significant quantities . A high level of for example 14 mg arsenic per liter will decrease the effectivness fluoride removal and it requires also treatment to reduce the arsenic content to acceptable levels.

In general, activated alumina is regarded as an excellent material for fluoride removal. Levels as low as 0.1 mg F per liter can be achieved if desired. The capacity of the medium decreases with an increase of pH or alkalinity; low alkalinity waters may require pH adjustment after fluoride removal. One particular advantage of activated alumina relates to the fact that, other than pH control where appropriate, pretreatment of the water is not normally needed. Activated alumina is considered better than bauxite or activated carbon. The efficiency of fluoride removal generally increases for lower fluoride levels in the untreated water. A comprehensive design manual for fluoride removal using activated alumina has recently been published . The basis of the capital and treatment costs have also been published.

The use of activated alumina may be appropriate for certain situations in some developing countries. Tests of its effectiveness have been evaluated in India and costs were estimated at about 2 to 4 Rupies per m³ treated water.

In summary, activated alumina is a superior medium for fluoride removal. The system using it is well tried and will operate for most types of water. In specific cases, however, other forms of treatment may be more cost-effective.

5. Conclusions

It is not possible here to specify which system should be used in particular cases, because there are many factors which need to be considered in deciding which method is the most appropriate. In developed countries activated alumina bone- char and reverse osmosis seem to be the more commonly favoured systems. In developing countries, treatment methods based on the combined use of lime and alum (Nalgonda technique and its variations), pre treated bone, bauxite, alumina, and defluoron-2 tend to have been used more often. The Nalgonda technique seems to have been particularly effective in India and could well be a suitable option in some other developing countries. However, in individual circumstances and in different countries and regions, a wide range of techniques have been applied. Some of the less well-tried methods, e.g. use of lime, use of alum, activated carbon, ion exchange methods and use of untreated bone, might be justified in exceptional cases. When both hardness and fluoride removal are needed, and where sufficient magnesium is present in the raw water, water softening can be an especially effective method. Alum treatment alone may not be very effective for fluoride removal unless massive doses of alum are used, and thus it is unlikely to be cost-effective.

The use of activated alumina, charred bone and lime with alum (Nalgonda technique) are usually regarded as the more cost-effective methods. In assessing costs in a particular case, however, factors such as plant life, media cost and regenerating and operating costs all need to be carefully

considered, taking particular account of local factors.

The fluoride absorbing capacity of different media is not an easy factor to define because it depends on the pH of the raw water, the regeneration history of the media and the competition between different anions and cations

In developing countries in particular, one needs to bear in mind the availability of local skills for plant operation and factors such as training of operators and their retraining on a regular basis. Again, in some developing countries, a regular supply of chemicals and spare parts may be difficult to guarantee, especially if they need to be imported. An overriding point to bear in mind is to keep the technique and plant as simple as possible. Thus, the possibility of blending with low-fluoride water should be considered as a first alternative before reviewing different treatment options.

Since the efficiency of any process will depend on the particular nature of the raw water and the quality of the treatment media and reagents used, it is essential to first make a feasibility study. The present literature review may be used as a starting point for obtaining basic information on different options. Literature references quoted in this guide can then be consulted for further details including process specifications and estimated costs. Secondly, it is strongly recommended that a bench-scale process followed by a pilot plant be set up and operated; this will determine any problems which may arise with a selected system in relation to a particular water type in a specific location. It should be borne in mind that pretreatment of the raw water may be necessary in some cases in order to make process more efficient and to achieve other concurrent water quality objectives.

These general conclusions relate to community water supply systems where water can be treated prior to distribution. Alternative treatment such as " point-of –use" systems may be effective and indeed more appropriate in some situations. Alternative or new sources, blending of water supplies and provision of bottled water are also options which have to be identified prior to identifying suitable treatment methods.

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Seepage and Embankment Cracking Analysis of the Mylomee Micro Earth Dam

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Abstract

Uneven distribution of rainfall in the major portion of Amhara Region including waghimra zone makes irrigation the best way to alleviate problems encountered due to water shortage. This is the only sustainable solution to overcome this problems by implementing modern irrigation activities like storage dams, ponds etc. Even though storage darns are very useful hydraulic structures, they need to have careful geotechnical and engineering geological investigations on which design and construction activities are based. In this paper it has been tried to show the practical evaluation and analytical determination of net loss of water from the reservoir of Mylomee irrigation project based on two approaches. The first methodology used for the determination of amount of water from the reservoir is water balance calculation and comparing it with the excessive seepage volume downstream of the dam body for the given specified time. From this we have found out that 90.6% of the lost water is identical, The second methodology used for the evaluation of amount loss of the reservoir water through the foundation using Darcy's formula and comparing it with the excessive seepage volume downstream of the dam body. From this we have found that 94.4% of the lost water is identical. The main reason for this leakage is the implemented cutoff at the centerline of the dam axis is not a positive cutoff but a partial cutoff with 50% penetration and this excessive seepage runs through the foundation of the dam body.

Key words; Seepage Cracking Foundation Cutoff Permeability

1. Introduction

Mylomee or/Asthakua/ micro earth dam irrigation project is found in North Eastern part of Amhara national regional state in Waghemira zone about 572km from Bahirdar town. The construction activity was started in June 1996 and completed in July 1998.

The geographic location of the project area is situated in the high land of Ethiopia at a distance of 13 km from Sekota town towards Northeast, at an elevation of about 2050m asl. The geographic coordinates of the area are 12°35N latitude and 39°22'E longitude. The mean minimum and the mean maximum temperature of the project area are 9.7°c and 26.4°c respectively.

The salient features of the project area described as follows.

Catchments area	6.25km^2
Net storage capacity	0.526Mm^3
Design flood	31 m^3/s
Dam type	Zoned dam
Maximum crest length	470m
Top width of dam	4.5m
Top core width	3.0m
Riverbed level	1962masl
Normal pool level	1981masl
Maximum dam crest level	1984masl
Irrigable area	55ha
Runoff coefficient	0.25
Nature of river	Intermittent

The implemented project used solely for irrigation purpose. Currently the construction of the dam, appurtenance structures and the farm irrigation systems were completed and the embankment was ready for full utilization. Unfortunately seepage and cracking problem occurred on the dam body.

This paper presents the determination of reservoir water leakage through the foundation and the possible recommendations for remedial measures to be taken based on practical design and construction experiences, and soil laboratory results during the successive site supervisions and office works.

1.1Previous study

1.1.1 Engineering geology

The left abutment of the dam is composed of generally silty clay soil on top underlain by slightly weathered basalt. The slope of this abutment is very gentle. On the basis of topography, the nature of rock and soil, the slope is found to be stable and no risk of water loss is expected.

The right abutment is mainly composed of slightly weathered basalt, exposed on the surface and becoming more fresh down ward. No joints were seen on the basalt which are often and continuous through out.

They are generally tight and filled with clays. Due to the nature of joints and the type of rocks, the right abutment is without slope instability problem and no leakage is expected along the joints since they are tight joints and are not continuous throughout.

1.1.2 Water tightness of reservoir area

Most of the reservoir area is covered with reddish co lour gravelly silty sand. The gully in the reservoir area near the left abutment is mainly composed of sand, which is pervious. In order to check the impervious condition of the reservoir at the place of the gully, it requires to dig a test pit to secure water loss underneath the sand. 10 geological test pits are taken in the reservoir area. (See geological topomap of the reservoir area fig.5)

1.1.3 Foundation condition

As to the result of the geological test pits, the basalt at the foundation is over laid by gravelly silty sand soil and highly weathered basalt. Since it is semi pervious, the permeability of this foundation material after the

identification of the soil type and its engineering properties it is found to be 2.0×10^{-5} m/s.

1.2 Assessment and analysis of the problems of excessive seepage

An excessive seepage was observed at the mid section of the rock toe about 120m to the left of the main river. The average concentrated leakage flow measured d/s of the dam body using floating method is 20 l/s. The following descriptions might also help to understand the extent of loss of reservoir water from end of July 1998 to end of December 1998 based on two approaches.

Methodology-1

Reservoir water level (end of July 1998) = 1976.86masl
Reservoir water level (end of Dec. 1998) = 1974.47masl
Reservoir water volume (end of July 1998) = 280000m³ (Area-Capacity curve)
Reservoir water volume (end of Dec. 1998) = 166520m³(Area-Capacity curve)

Expected evaporation loss = 28620m³
Expected sediment load = 3187.5m³
Precipitation on the reservoir = 7200m³
Runoff volume from 80% dependable rainfall = 222125m³

*Because of the absence of rainfall data for the project area in the specified time we have used the 80% dependable rainfall of the project area as input. (See Table -1 below.)

Net loss (end of July 1998- end of December 1998) = initial storage+ surface runoff + precipitation + sediment load -evaporation -final storage (1)

Net loss=280000 + (159437.5 + 62687) + 7200 + 3187.5 – 28620 - 166520
Net loss =317372 m³

The expected amount of concentrated average seepage measured d/s from end of July 1998 to end of December 1998 including evaporation

Net loss (end of July 1998 – end of December 1998)=Total seepage volume + evaporation (2)

Net loss= (20* 10^{-3} *5*30*24*60*60) +28620
Net loss= 287820 m³

No.	Month	P=80% dep. R.F(mm)	Q=Runoff Volume (m^3)	Measured Volume (m^3)
1	January	0	0	
2	February	0	0	
3	March	0	0	
4	April	0	0	
5	May	14.32	22323	
6	June	45.41	70959	
7	July	132.09	206390.63	280000
8	August	102.04	159437.5	
9	September	40.12	62687.5	
10	October	0	0	
11	November	0	0	
12	December	0	0	166520

Table-1 Rainfall - Runoff relationship using Q = C P A

Where
Q = Runoff in (m³)
C = Runoff coefficient
P = Dependable rainfall in (m)
A = Catchments area in (m²)

Comparing the above two losses (1) and (2) 90.6% identical.

Methodology-2

The probable cause of this excessive seepage is regarded as the combination of geological factors and improper way of construction activity. During site supervision, after complete draw dawn of the reservoir water, it has been found that the top reservoir bed material was used as a quarry for construction material. During this investigation there was undetected old buried river found at a depth of 2.5m below the existing reservoir bed. This old buried channel was not found at the detail design stage,

To estimate the volume of the under seepage which may be expected, it is necessary to determine the coefficient of permeability of the foundation material at the field. Upon determination of the coefficient of permeability of the foundation, approximation of the amount of under seepage may be made by use Darcy's formula.(see fig. 1)

q =KIA

Where,
q - rate of seepage in given time per width (m³/s/m)
K-coefficient of permeability for the foundation (m/s)
L-crest length of the dam (m)
I- hydraulic gradient (H/B)
A-gross area of foundation through which flow takes place (m²/m)

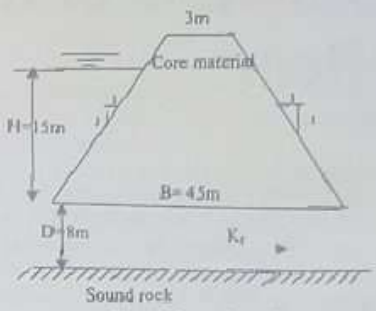

Fig. 1 Sound rock

Note: - Dimensions are not to scale
From fig.- 1 given
H - head of reservoir water level =15m
D - depth of pervious foundation material = 8m
K_f - permeability of foundation material = 2×10^{-5} m/s
q = 2 x 10^{-5} (15/45) x 8 x 1
q = 5.33 x 10^{-5}m³/s/m

The total amount of volume water seeping through the foundation from end of July to end of December 1998 along the dam axis of the crest length i.e. 470m estimated to be,

V= q x L x time
V=5.33 x 10^{-5}x 470 x 5 x 30 x 24 x 60 x 60
V= 324864m³

Case-B

When the trench cuts off pervious foundation and back filled with impervious material, the rate of seepage can be obtained by the following formula (see fig.2)

$$\frac{q_c}{k_f H} = \frac{1}{0.88 + \frac{B}{D} + \left(\frac{K_f}{K_g} - 1\right)\frac{E}{D}}$$

Where
q_c - Rate of seepage per unit length of the dam
K_f - permeability of the foundation material
H - Head of water in the reservoir
B - Width of the dam base (core width of the dam)
D - thickness of the pervious layer
K_g - Permeability of impervious fill in trench

E - thickness of cutoff

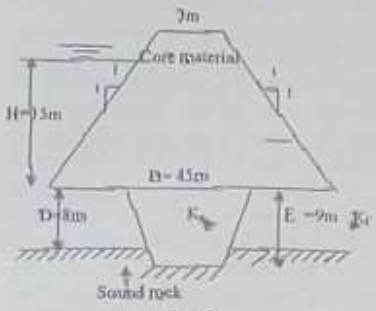

Fig 2

Note: Dimensions are not to scale
Accordingly for this case
K_f = 2x 10^{-3} m/s (for poorly graded sand of foundation material)
H = 15m
B = 45m
D = 8m (maximum)
K_s = 2.1 X 10^{-4} cm/s
E = 9m

Substituting this value in the above formula we get $q_s = 2.78 \times 10^{-7}$ m³/s/m

Amount of permissible volume of water seeping through the cutoff from end of July 1998 to end December 1998 along the dam axis of the crest length that is 470m estimated

$V = q_s \times L \times$ time
$V = 2.78 \times 10^{-7} \times 470 \times 5 \times 30 \times 24 \times 60 \times 60$
$V = 1693.35$ m³

If there were a positive cutoff at the centerline of the dam axis, the amount excessive seepage would be reduced by 99.48%.

During supervision time we have taken 10 geological test pits around the dam body in the reservoir to know the actual depth of the impervious stratum and the nature of the foundation material. From this investigation the actual sound rock of the impervious stratum is found at a depth of 8m below the riverbed. The existing implemented cutoff at the centerline of the dam axis is with a thickness of 4m below the riverbed level. This indicates that it is a partial cutoff. Turnbull and Creager* on homogeneous isotropic pervious foundation have demonstrated that 50% cutoff penetration is required to reduce the seepage 25%. Amount of rate of seepage by partial cutoff with 50% cutoff penetration

$q_p = 5.33 \times 10^{-7} \times 0.75$
$q_p = 3.99 \times 10^{-5}$ m³ /s/m

Therefore, amount of volume of seeping water through the foundation
$V = q_p \times L \times$ time
$V = 3.99 \times 10^{-5} \times 470 \times 5 \times 30 \times 24 \times 60 \times 60$
$V = 243038.8$m³

Net loss (end of July1998-end of December 1998) = Total seepage volume + evaporation (3)

Net loss = 243038.8+28620
Net loss = 271658.8 m³

Comparing the above two losses (2) and (3) 94.4% identical.

1.3 Assessment and Analysis of the problems of cracking

The first filling of a reservoir is a critical period for most dams because of the changes in the deformation pattern due to water loading and the effects of saturation on the in place fill materials. The rate of filling has an important bearing on the severity of the effects on the dam. Where as the dam may adjust to a slowly rising pool, a rapid filling of the reservoir might possibly cause some structural distress, such as formation of cracks in the core or shell.

The crack observed in the specified project is longitudinal cracking extending over 228m paralleling to the axis of the dam with in the middle part of the dam. The minimum and the maximum depth of the crack are 20cm and 90cm respectively with a maximum width of 15cm. The cause of longitudinal cracking in the respected dam might be indicated due to the following reasons.

a. Due to relatively high post construction settlements resulting from inadequate compaction and inadequate water content

b. Compression of foundation soils on the upstream portion of the dam that softens on wetting during the first reservoir filling.

c. The differential settlement between the shell and the core material.

14 members of monuments were installed on both sides of the top of the dam crest and their elevations were also recorded. The purpose of these installed monuments on the dam is to study the horizontal and vertical settlement of the dam body on the basis of the compressibility and consolidation of the dam material and foundation respectively. But after successive readings with in a year, there were no significance elevation differences as the original. This indicates that there is no vertical settlement.

2. Remedial Measures for Cracking

Remedial measures for cracking are not as such possible before its extent is known through time. The main danger associated with longitudinal cracks is that may occur in con unction with other unseen cracks running transversely through the core. Longitudinal cracks should be carefully observed and when movement stops filled by trenching and back filling with compacted impervious soils. Since the crack is of appreciable depth, length and width, it should be tried to prevent it from filling with surface wates. (see figure 4.)

3. Remedial Measures For The Seepage Water Through The Foundation

Two options are seen to treat the problems

1. Provision of upstream impervious blanket
2. Provision of upstream cutoff trench

3.1 Upstream impervious blanket

When a positive cutoff to the underlying impervious stratum is expensive and some leakage is permissible or when the depth to the underlying impervious stratum is great and a positive cutoff is not feasible and the foundation permeability is moderately high, reduction of seepage and overall seepage gradients may be accomplished by construction of an upstream impervious blanket of the reservoir area.

3.2 Design of impervious blanket

When the pervious foundation is cutoff by a trench and back filled with impervious material the rate of seepage can be obtained by the equation.

$$\frac{q_s}{k_f H} = \frac{1}{0.88 \frac{B}{D} + \left(\frac{K_f}{K_s} - 1\right)\frac{E}{D}}$$

Where

q_c - Rate of seepage per unit length of the dam

K_f - permeability of the foundation material

H - Head of water in the reservoir

B - Width of the dam base (core width of the dam)

D - thickness of the pervious layer

K_s - Permeability of impervious fill in trench

E - thickness of cutoff

Accordingly for this case

$K_f = 2.x\ 10^{-5}$ m/s (for gravelly silly sand of foundation material)

H = 15m

B = 45m

D = 8m (maximum)

$K_s = 2.1 \times 10^{-6}$ cm/s

E = 9m

Substituting this value we get $q_c = 2.78 \times 10^{-7}$ m³/s/m

For a dam with an impervious blanket, Dachler* derived the following equation which agrees with the results of electrical analogy models.

$$\frac{q_c}{k_f H} = \frac{1}{0.88 + \frac{B + B_1}{D}} \quad For\ (B + B' > 2D)$$

Where B' is length of upstream impervious blanket substituting 'q_c' and all other value we get.

B + B' = 8626m > 2D Ok!

Therefore B' = 8626-45=8581m (un-practical for small dam)

Although blankets may be designed by theoretical means a simplified approach may be used for small dams. A suitable thickness for small dams is 10 percent of the depth of the reservoir above the blanket, with a minimum thickness of 0.9m. Accordingly maximum blanket thickness

= 10% (maximum water depth)

= 10% x 19

= 1.9m say 2.0m

Even if the width of the blanket may vary according to the site topographical condition, the average width of delineated from the top map (1:1000) is above 280m.

3.3 Upstream cutoff trench

When ever economically possible, seepage through foundation should be cutoff by a trench extending and keyed to the bed rock on other impervious stratum and back filled with impervious material. This is the most positive way of controlling seepage and ensuring that no problems will be encountered either from piping through the foundation or heave due to excessive seepage pressure at the down stream toe. The possible and economically acceptable depth in this case varies depending on the local geological conditions. A minimum bottom width of 4m is provided to enable smooth operation of excavating and compacting equipment through out the longitudinal section.

4. Conclusion And Recommendations

4.1 Conclusion

Considerations that influence the selection of the type of seepage control measures to be adopted are depth of foundation, nature foundation strata and material including permeability of different layers, likely seepage losses and degree of control requires, relative economics of different alternatives, the risk element as influenced by the height of dam and the seriousness of the consequences of failure.

The amount of water, that was lost from the reservoir due to excessive seepage, is 287820m³. But based on successive site supervisions and results of geological test pits, we have found out that the existing implemented cutoff at the center line of the dam axis is not positive cutoff but a partial cutoff. This conclusion is drawn out analytically based on hydraulic computation of seepage water through the foundation material. The amount of rate of seepage water would be reduced only by 25% with 50% cutoff penetration. i.e. 75% of 324864m³ or 243648m³ of the reservoir water lost through this partial cutoff. Therefore 94.4% of the reservoir water lost under the implemented cut off is identical and this cutoff is not a positive cutoff.

4.2 Recommendations

-Taking into consideration the in availability of sufficient amounts of construction material in the vicinity of the project area especially clay material the construction of u/s cutoff up to impervious straturn and keyed in to it is appropriate.

-The stripping of natural blanket up stream from the dam in the reservoir to secure impervious soil for the construction of the dam should be avoided when a positive cutoff is not provided in the design.

-The cutoff provided upstream of the dam 8m from the toe of the upstream shell is a positive cutoff. Therefore this cutoff should be properly jointed with the core material. The material used for jointing the upstream cutoff and the central core material should be the same and it has a nominal thickness of 2m. (See fig. 3.)

All assumptions in the Darcy's equation are valid.

5.Acknowlegments

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Stressed Irrigation And Production Function A Case Study In The Hare Command Area

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Abstract

The differential nature of crop yield response to different levels of soil moisture content available to it gives rise to the concept of water production functions of crops. The functional relationship between variables quantifying the water input and crop output, namely the crop yield is water production function. A key limitation of water production functions is that they largely fail to account for human attitudes, values and reactions, i. e. these are based on simplified assumptions. In the present paper an attempt has been made to study the use of production functions in obtaining yield reduction for the cereal crop maize in the Hare command area. For 10%, 20%, 30%, 40% and 50 % reduction in ET_c the Jensen's (1968) model and Rao et. al (1988) model have shown slightly curved relation with similar results while Stewart et. al model(1976) gave relatively straight line and high deviation as compared to the other two models after 38.46% reduction in ET_c. Therefore, either of the first two methods may be used in locations where experimental data on crop water use and yield are sparse.

1.Introduction

Water deficit or water stress refers to a situation in which plant water potential and turgidity are reduced to such a level as to interfere with normal functioning of plants. The important processes affected are: loss in turgidity, decrease in protoplasmic viscosity, decrease in process of photosynthesis, initial rise in respiratory rate and subsequently fall in it as water stress increases (Sree Ramulu, 1998). The crop water requirements for the healthy growth of crop which draws water from the soil through its root system, provided sufficient water is available in the so called 'soil reservoir'. While this reservoir starts depleting, the crop continues to draw their requirements. For some level of depletion level, the crop can draw the total requirements (Let us call it ET_p), but after some depletion level, though the crop can still draw the water, the water drawn is less and this condition is known as stress or deficit condition. The actual water that can be drawn by the crop is called actual evapotranspiration (ET_a). Thus value of the ratio gets progressively reduced with the depletion level. As soil moisture stress increases photosynthesis drops to a compensation point and directly affects the various biochemical processes and indirectly reduces the intake of carbon dioxide through the stomata.

2. Methodology

2.1Water Production Function of crops

The differential nature of crop yield response to different levels of soil moisture content available to it, gives rise to the concept of water production functions of crops. The functional relationship between variables quantifying the water input and crop output, namely, the crop yield, is called the water production function. Even when water is considered the only controllable input, the crop water – yield relationship is quite complex. This is because the economic yield of a crop depends not only on the total water supplied during the growing season but also on its temporal allocation. Distinction is, therefore, made between a water production function, which is derived for the total water used by the crop in the entire season and the dated production function that depends on the time distribution of the quantities of water used. The former can be considered to be an implicit dated production function with a fixed seasonal distribution of water while the latter is derived based on flexible distribution of water supplies. Both seasonal and dated water production functions are useful at different stages of irrigation planning and management.

2.1 Water Variables Associated with Crop Yield

The primary question involved in the development of water production functions (i. e. Seasonal or dated) relates to the choice of the independent variable (x), the dependent one being crop yield (y). Mathematically the functions may be represented as

$$y = f(x) \quad \ldots\ldots\ldots\ldots (1)$$

As per Stewart (1980) x may be reasonably represented by:

i) The actual depth of irrigation water applied (I)

ii) The total field water supply (FWS) (i.e. FWS = effective rainfall + Irrigation + stored soil moisture), or

iii) Indirectly by the crop evapotranspiration (ET_c)

Effective rainfall (ER) represents that portion of the rainfall, which becomes available to the crop through the soil water reservoir. When Irrigation (I) is used to represent water use, transferability to other sites and seasons is not feasible as the water used by the crop comes from rain as well as from the stored soil moisture. Further, some

of the irrigation water may be lost as drainage or runoff or be stored in the soil and is not accounted for. Some of these difficulties are also encountered if FWS is taken as the independent variable. Such difficulties are not encountered when ET is chosen as the independent variable. In present case since actual depth of irrigation and total field water supply are not known, therefore, ET has been used as the independent variable. Also, once Y Vs ET functions are developed, they can be easily translated into Y Vs I, or Y Vs FWS functions using the soil water balance. But, ET is an indirect measure of water use and needs to be estimated from the soil water balance. Water production functions based on both ET and I have been applied in irrigation planning and scheduling. Some of the advantages and disadvantages of ET formulations are as discussed below separately for seasonal and dated water production functions.

2.2 Seasonal Water Production Functions

Most early researchers (Dewit, 1958; Hanks et. al., 1969) tried to relate transpiration (T) and crop growth (G) as determined by the total dry matter production. They found that, for several crops, functions of cumulative G Vs cumulative T were generally linear. Whether the economic crop yields (Y) Vs T functions are also linear depends on how the ratio (Y/G), which is called the harvest index, changes with water deficits. If this rate is constant or changes in a steady fashion with the transpiration, then the yield transpiration relationship can also be treated as linear, (Stewart et. al., 1974). Considerable evidence from field experiments at several locations on India and elsewhere indicates that Y Vs seasonal ET functions for many crops are also linear. Stewart et. al (1974) proposed a relationship of the form:

$$\left(1-\frac{Y}{Y_m}\right)=b\left(1-\frac{AET}{PET}\right)_{season} \quad \text{.....(2)}$$

Where Y_m is the maximum possible crop yield when water is not limited and b is a coefficient, which varies with crop and location. Many studies indicated that the growth stage of crops during which water stress occurs might have a significant effect on yield response. In order to distinguish between the specific growth stage effects and net seasonal water use, the effects of moisture stress were categorized as of two types. The primary effect is of water shortage per season. By this, any seasonal ET deficit will lead to reduced yields. The secondary reduction in yield may result from the stages of crop growth at which the stress occurs. Linear relationships of the types given by equation 2 are valid so long as severe moisture stress in any growth stage is avoided and the stress is distributed more or less, uniformly over the growing season. Thus, the seasonal water production functions are not useful for characterizing the relative sensitivity of different crop growth periods.

2.3 Dated Water Production Functions of Crops

Dated water production functions incorporate effects of both timings and quantities of water applications on crop yield. The number of time periods considered as arbitrary and are usually chosen to coincide with the physiological stages of crop growth or with some convenient time interval such as a month. Evapotranspiration or irrigation depth may be used to represent the water-use variable in these functions; out of these, for present case ET has been considered as a variable.

Moore (1961) was one of the first to recognize the problem of deficit irrigation water allocation over time on a mathematical model framework. He reviewed irrigation applications and made the following assumptions in deriving the production function:

i) Soil moisture stress in each cycle, expressed as a percentage of potential growth,

ii) The actual growth in each cycle, expressed as a percentage of potential growth, is monotonously decreasing function of the relative depletion of available moisture in the root zone,

iii) The relative potential growth of the harvestable plant part is assumed to be linear over time, from sowing to the time of harvest and

iv) The growth in each cycle is independent of the growth in the previous periods and the total actual growth is obtainable by summing the actual growth increments from independent irrigation cycles.

The general procedure for deriving production function models may be categorized in the following steps:

i) Divide the crop-growing season into convenient intervals (The usual preference is to make the intervals coincide with physiological growth stages).

ii) Conduct several irrigation experiments in which varying degrees of soil moisture stress are created in each time period.

iii)Quantify the stress in each period using soil moisture or or transpiration (T) or relative evapotranspiration deficit as the variable representing water use in that period.

iv)The dated production function representing the combined effects of stress in different time periods is postulated heuristically. This is done by assuming that the stress effects in different time periods are independent and that combined effects of stress in several stages are either additive or multiplicative.

v)The parameters of the production functions are usually determined by regression analysis and are called yield response factors for the corresponding time periods.

Out of the well known dated water production functions which are derived in the above fashion, Jensen (1968), Rao et. al. (1988) and Stewart et al.(1976) models have been used in the present case as given in Table – 1.

The field data of irrigation management experiments gainfully employed to derive the dated water production functions. This would require the use of local meteorological data and an appropriate soil water balance model to determine the daily evapotranspiration and available soil moisture for the various irrigation treatments. The actual and potential evapotranspiration on each growth period can be determined by cumulating the corresponding daily values. The coefficients of this function can be determined by regression analysis using the yield data.

Table – 1 Production Functions Used for the Study

Author(s)	Production Functions	Independent Variables
Jensen (1968)	$\prod_{i=1}^{n} (AET/PET)^{\lambda_i}$	Relative ET
Stewart et. al (1976)	$1-\sum_{i=1}^{n} YRR_i(1-AET/PET)_i$	Relative ET deficit
Rao et. al (1988)	$\prod_{i=1}^{n} (1-K_{si}(1-AET/PET)_i$	Relative ET deficit

2.4 Comparison Between Different Models

Different researchers in different areas collected data from field experiments and tried to compare them. Based up on these results the following general observations have been made by the CBIP (1991):

i) Both additive and multiplicative formulations of dated water production functions can predict crop yield with in reasonable limits.

ii) The parameters of these functions need to be determined locally that is, dated production functions are location specific,

iii)Despite their approximate nature, they can be usefully employed in irrigation optimization models.

The development of dated production functions requires extensive local experimental data, which is not always available in several irrigation project areas in developing countries like Ethiopia and India. Recognizing this, Doorenbos and Kassam (1979) analyzed the available information on crop yield (Y) response to water and empirically derived yield response factors, K_y. These factors are sensitivity indices for water stress in specified physiological growth stages (indicated by i) of crops and are given by the following equation:

$$\left(1-\frac{Y}{Y_m}\right) = K_y\left(1-\frac{AET}{PET}\right) \qquad \text{.....(3)}$$

PET is governed by climatic conditions alone when soil moisture availability does not limit evapotranspiration. Y_m is the maximum crop yield that can be obtained when water is not limiting (i.e. when AET = PET). The above equation is valid for most crops for water deficits in the range

Water deficits of this order are not usually exceeded for well-adopted varieties grown under irrigated conditions. About 80 to 85 percent of the observed yield variation at different locations was explained by this relationship (CBIP, 199). The response factors K_y were, therefore, recommended for planning and operation of irrigation systems. So this equation has been validated and used by several others to predict crop yield responses at several locations in USA, China, Korea etc (Allen, 1986; CBIP, 1991).

In spite of its wide applicability, Equation (3) is not directly useful in irrigation scheduling with limited water supplies. This is because, the yield response factors K_y quantify the effect of water stress in specified growth stages. For application in deriving optimal irrigation schedules, they need to be combined into dated *water production function*. The crop growing season is divided into N growth stages (i=1,2, ...,N) which coincide with the vegetative, flowering, grain formation and maturity stages of crop growth. Then, if the water deficit occurs in the first (vegetative) growth period alone, the resulting yield Y_1 will be given by the following equation

$$f_1 = \frac{Y_1}{Y_m} = 1 - K_{y1}\left(1 - AET/PET\right) \qquad \text{.....(4)}$$

In which the suffix 1 refers to the first growth stage. The response to water deficits occurring in any one of the other growth stages (i = 2, 3, 4) will be given by relationships similar to equation 4 with K_{y1} replaced by K_{y2}, K_{y3}, and K_{y4}. For water deficits in more than one crop growth stage, the dated water production function quantifying their combined effect is:

$$F = F(f_1, f_2, \ldots, f_n) \qquad \text{.....(5)}$$

In which N is the number of growth stages for which the values of k_y are known. The following three formulations of the function 'F' may be considered (Rao et al, 1988):

i) Additive Model:

$$F = \frac{Y}{Y_m} = 1 - \sum_{i=1}^{n} K_{yi}\left(1-\frac{AET}{PET}\right)_i \qquad \text{.....(6)}$$

Equation 6 is identical to the dated production function of Stewart et. al (1976) in which K_{yi} replaces the yield response ratio YRR.

ii) The general multiplicative power function form after Jensen (1968):

$$F = \frac{Y}{Y_m} = \prod_{i=1}^{n}\left(\frac{AET}{PET}\right)^{\lambda_i} \qquad \text{.....(7)}$$

λ_i is a sensitivity factor which can be determined graphically using the following equations (Tsakiris, 1982):

$$\frac{Y_i}{Y_m} = \left(\frac{AET}{PET}\right)^{\lambda_i} \qquad \text{.....(8)}$$

$$\text{or } ln\left(\frac{Y_i}{Y_m}\right) = \lambda_i * ln\left(\frac{AET}{PET}\right)$$

$$\text{or } \lambda_i = \ln\left(\frac{Y_i}{Y_m}\right) \Big/ \ln\left(\frac{AET}{PET}\right) \qquad \text{.....(9)}$$

The values of λ_i corresponding to each value of K_{yi} listed by Doorenbos and Kassam (1979) can be obtained from equation 9 as given in Table –2 (CBIP, 1991)

3.Results And Discussion

Partial irrigation is supplying less water than a crop needs for full production. The Government of Ethiopia is working hard increase food production so as to meet the rising demands of the rapidly expanding population. The simplest and most effective option to implement partial irrigation is by planting more crops and increasing crop intensity. AS the irrigation systems are developed for less than 100% cropping intensity, this indicates that de facto partial irrigation is already widely practiced in the country. The effects of stressed irrigation and production functions have been studied for the crop maize in the Hare command area.

Table: 2 Values of λ_i corresponding to different values of K_i

K_i	0.20	0.25	0.30	0.40	0.45	0.50	0.55	0.60	0.75	0.80	1.00	1.50
λ_i	0.15	0.19	0.24	0.32	0.37	0.42	0.47	0.52	0.68	0.74	1.00	1.95

3.1 An Illustrated Example: Crop: Maize

Let K_y=1, AET=3.23 mm/day and PET 3.63 mm/day

$$1 - \frac{y_a}{y_m} = k_y\left(1 - \frac{AET}{PET}\right) \quad \textit{Additive Model:}$$

$$\Rightarrow 1 - \frac{y_a}{y_m} = 1\left(1 - \frac{3.23}{3.63}\right)$$

$$\Rightarrow \frac{y_a}{y_m} = 0.889$$

Multiplicateive Model

$$\ln\left(\frac{y_a}{y_m}\right) = \lambda_i \ln\left(\frac{AET}{PET}\right)$$

$$\Rightarrow \ln(0.889) = \lambda_i \ln(3.23/\ 3.63)$$

$$\Rightarrow -0.117 = \lambda_i(-0.117)$$

$$\Rightarrow \lambda_i = 1.0$$

The third formulation is a simple multiplicative model:

$$F = \frac{Y}{Y_m} = \prod_{i=1}^{N}\left(1 - K_i\left(1 - \frac{AET}{PET}\right)_i\right) \quad \ldots(10)$$

This is based on the heuristic assumption that the Boolean principle is applicable and the yield expected at the end of any growth stage is determined with respect to the maximum yield expected at the beginning of that stage.

The above three dated water production functions models (Equations 6, 7 and 10) derived from crop growth stage yield response factors K_i given by Doorenbos and Kassam (1979) were compared by Rao et al (1988). It was concluded that the sample heuristic multiplicative form (Equation 9) is applicable over a wide range of stressed conditions. This form can be used in locations where experimental data on crop water use and yield are sparse, e.g. for the cropMaize (Desalegne et. al, 2000):

Groth Stages	A	B	C	D
ETa (AET)	1.7	3.4	4.35	3.46
ETm (PET)	2.10	3.55	4.67	3.46
K_y	0.4	1.5	0.5	0.20
λ_i	0.32	1.95	0.42	0.15

Solution:Method I (after Jensen, 1968):

$$\frac{y_a}{y_m} = \left(\frac{AET_1}{PET_1}\right)^{\lambda_1} * \left(\frac{AET_2}{PET_2}\right)^{\lambda_2} * \left(\frac{AET_3}{PET_3}\right)^{\lambda_3} * \left(\frac{AET_4}{PET_4}\right)^{\lambda_4}$$

$$\frac{y_a}{y_m} = \left(\frac{1.7}{2.10}\right)^{0.32} * \left(\frac{3.4}{3.55}\right)^{1.95} * \left(\frac{4.35}{4.67}\right)^{0.42} * \left(\frac{3.46}{3.46}\right)^{0.15}$$

$$= (0.935)\ (0.919)\ (0.971)\ (1.0) \Rightarrow 0.834$$

$\therefore$ *Yield reduction* $= 1 - \frac{y_a}{y_m} = 1 - 0.834$

$\Rightarrow$ *Yield Reduction* $= 16.6\%$

$$F = \frac{y_a}{y_m} = \prod_{i=1}^{n}\left(1 - K_i\left(1 - \frac{AET}{PET}\right)_i\right)$$

$$\Rightarrow \frac{Y_a}{Y_m} = \left(1 - 0.4\left(1 - \frac{1.7}{2.1}\right)\right) * \left(1 - 15\left(1 - \frac{3.4}{3.55}\right)\right) * \left(1 - 0.5\left(1 - \frac{4.35}{4.67}\right)\right) * \left(1 - 0.2\left(1 - \frac{3.46}{3.46}\right)\right)$$

$$\Rightarrow \frac{Y_a}{Y_m} = (0.924) * (0.937) * (0.966) * (1)$$

$$= 0.836$$

$\therefore$ *Yield reduction* $= 1 - 0.836 = 16.4\%$

Method II(after Rao et. al, 1998):

$$F = 1 - \sum_{i=1}^{n} K_i\left(1 - \frac{AET}{PET}\right)_i$$

$$\frac{y_a}{y_m} = 1 - 0.4\left(1 - \frac{1.7}{2.1}\right) + 1.5\left(1 - \frac{3.4}{3.55}\right) + 0.5\left(1 - \frac{4.35}{4.67}\right)$$

$$\frac{y_a}{y_m} = 1 - 0.076 + 0.063 + 0.034$$

$$\frac{y_a}{y_m} = 0.827$$

$\therefore$ Yield reduction $= 1 - 0.827 = 17.3\%$

Method III (after Stewart et. al, 1976):

Therefore we can conclude that almost there is no difference in all the above three models of production function. Further, the yield reduction for ET_a equal to different percentage of ET_c e.g. 10 %, 20%, 30%, 40%, and 50% are calculated by the above three models as follows and the results are as tabulated in Table 3.

Table: 3. Results of Yield Production Functions Models with Percentage Reduction in ET_c

Reduction in ET_c %	10	20	30	40	50
Jensen (1968)	26	47	64	76	86
Rao et. al (1988)	24	44	61	75	87
Stewart et. al (1976)	26	52	78	104	130

3.2 Sample Calculation For ET_a with 10% of ET_c Reduction

The data for the crop maize is as given in below:

Stages	A	B	C	D
ET_a	2.10	3.55	4.67	3.46
ET_c	1.89	3.20	4.20	3.11
$\frac{ET_a}{ET_m}$	0.90	0.90	0.90	0.90
K_y	0.40	1.5	0.5	0.20
λ_i	0.32	1.95	0.42	0.15

Jensen(1968) Method:

$$y_a/y_{max} = (0.90)^{0.32} * (0.90)^{1.95} * (0.90)^{0.42} * (0.90)^{0.15}$$

$$\Rightarrow y_a/y_{max} = (0.97) * (0.81) * (0.96) * (0.98)$$

$$\Rightarrow y_a/y_{max} = 0.73918$$

$\therefore$ Yield reduction $= 1 - 0.73918 = 26.08\% = 26\%$ (say)

Rao et. al (1988) Method:

$$y_a/y_{max} = (1 - 0.4(1 - 0.9)) * (1 - 1.5(1 - 0.9)) * (1 - 0.5(1 - 0.9)) * (1 - 0.20(1 - 0.9))$$

$$\Rightarrow y_a/y_{max} = (0.96)\ (0.85)\ (0.95)\ (0.98)$$

$$\Rightarrow y_a/y_{max} = 0.75969$$

$\therefore$ Yield reduction $= 1 - 0.75969 = 24.03\% = 24\%$

Stewart et. al (1976) Method:

$$y_a/y_{max} = 1 - 0.4\ (0.1) + 1.5(0.1) + 0.5(0.1) + 0.2(0.1)$$

$$y_a/y_{max} = 1 - 0.04 + 0.15 + 0.05 + 0.02$$

$$y_a/y_{max} = 0.74$$

$\therefore$ Yield reduction $= 1 - 0.74 = 26\%$

Likewise we can calculate for 20%, 30%, 40% and 50% reduction in ET_c. The percentage reduction has to be minimum in order to get minimum yield reduction. Therefore, 10% reduction of ET_c is recommended in this case during the period when there is scarcity of irrigation water. From this, it is clear that Stewart et. al (1976) model will not be functional after 38.46% reduction in ET_c. Graphical comparison of the output of the production function is as shown in the Figure 1.

4. Conclusions

An attempt was made to study the use of production functions in obtaining yield reduction for cereal crops in

the Hare command area. The crop selected for the study was maize which is a very common crop grown by the local farmers. For 10%, 20%, 30%, 40% and 50 % reduction in ET_c the Jensen's (1968) model and Rao et. al (1988) model have shown slightly curved relation with similar results while Stewart et. al model(1976) gave relatively straight line and high deviation as compared to the other two models after 38.46% reduction in ET_c. Hence either of the first two methods may be used in locations where experimental data on crop water use and yield are sparse.

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Sprinkler Irrigation by Gravity : Lessons from the Finchaa valley, Ethiopia.

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Abstract

The unique feature of sprinkler irrigation system is its ability to apply water in the form of sprays similar to that of rain. This is achieved by the simple mechanisms of sprinkler components which are set to rotate by the action of water jet rushing out through small nozzles under high pressure.

In this paper, a short account on the suitability of the land terrain of the Finchaa valley for sprinkler irrigation, the design parameters and management considerations of the sprinkler irrigation system powered by gravity are presented. Finally, the paper concludes by in-sighting a further study of such irrigation methods to other localities wherever the water and soil resources, the land terrain and other technicalities are in favour.

1.Introduction

Irrigation development has always been essential to expand agricultural activities towards arid and semiarid areas. For such development the availability of adequate water source and determining its methods of conveyance and delivery to the crop fields is as essential as the availability of the irrigable land. Based on this, the sprinkler irrigation system was selected as the most suitable irrigation method to grow sugarcane at the Finchaa valley.

The Finchaa valley is located at the foot hill of the steep (almost vertical) escarpment surrounding the valley in the east, south and west directions. Further more the land is bisected by the Finchaa river flowing from south to north until it joins the Blue Nile river.

The land terrain (topography) of the valley which drains towards (more or less perpendicular to) the Finchaa river has given a unique opportunity to introduce & operate sprinkler irrigation systems from the pressure created by gravity due to elevation differences from the canal to the crop fields.

This paper describes the general considerations followed in designing the sprinkler irrigation system with a brief explanations of its operational flexibility and the sustainability of the system when powered by gravity.

2.Background

Finchaa Valley where the Finchaa Sugar Factory is established is situated in the Eastern Wollega zone of the Region 4 of Ethiopia within the general boundaries of 9°15' to 10°00'N and 37°15' to 37°30'E. The topography of the valley is dominated by its undulating nature ranging between an altitude of 1350 and 1600m a.s.l. which is surrounded by escarpment caps in both the three directions.

According to the Ethiopian Agroclimatic zone classification (Hurni 1986) the region has both wet Kola and wet Weyna Dega climate based on the weather data collected at the central part of the valley .

The valley experiences an alternate wet and dry seasons with the major rains falling between June and September. The mean annual rainfall is about 1300 mm with 87% of which falling from June to September. The long term mean annual class A pan evaporation is 2530 mm while the maximum and minimum daily temperatures are 34°C and 11 °c respectively (Booker Tate. 1994).

Most of the soils in the valley have developed from Alluvial and Colluvial deposits derived from the surrounding rock formation in the escarpment. Some soils have been formed from basement complex rocks in-situ. As reported by Girma et. al (1996) the two major soil types are of the red to reddish brown friable Luvisols (75%) and the black heavy clay Eutric Vertisols (25%). However there is not a well defined boundary between the two soil types which made it difficult to have an independent irrigation design for each soil type.

Table 1. Area and Elevation of Fields under Sprinkler irrigation by gravity

LOCATION	AREA (Ha.)	INLET ELEVATION (m)	FIELD ELEVATION (m)	
			Upper	Lower
001B	400	1567	1510	1468
001N	665	1569	1551	1442
003B	805	1562	1487	1394
001B	790	1562	1487	1378
001E	330	1568	1496	1450
001C	1005	1580	1492	1386
001E	860	1560	1454	1384

The water from the Finchaa river is diverted by a weir to a canal at an elevation of 1600 meters ending after 44 km. of stretch at about 1540 meters a.m.s.l. However the gravity irrigated fields are found between 1510 to 1380 meters of elevation (see Table 1).

The land features are not only undulating topography but there are also many gully intrusions and intermittent streams discharging to the centrally bisecting Finchaa river as shown in Fig 1

This type of land feature of the valley has given a favourable condition of drainage from the fields that are designed for irrigation so that the Finchaa river is serving as the main drainage system of the catchment while the intermittent streams serve as secondary drains.

The water requirement of the sugar cane is fulfilled by irrigation and rainfall. There is no need of irrigation during the months June to September as the rainfall amount is sufficient to satisfy the crop water requirements. Nevertheless irrigation is essential in the remaining months to attain a sustainable yield.

3. The Irrigation System

The irrigation system comprises of three major components, namely, the conveyance system, the distribution system and the application system.

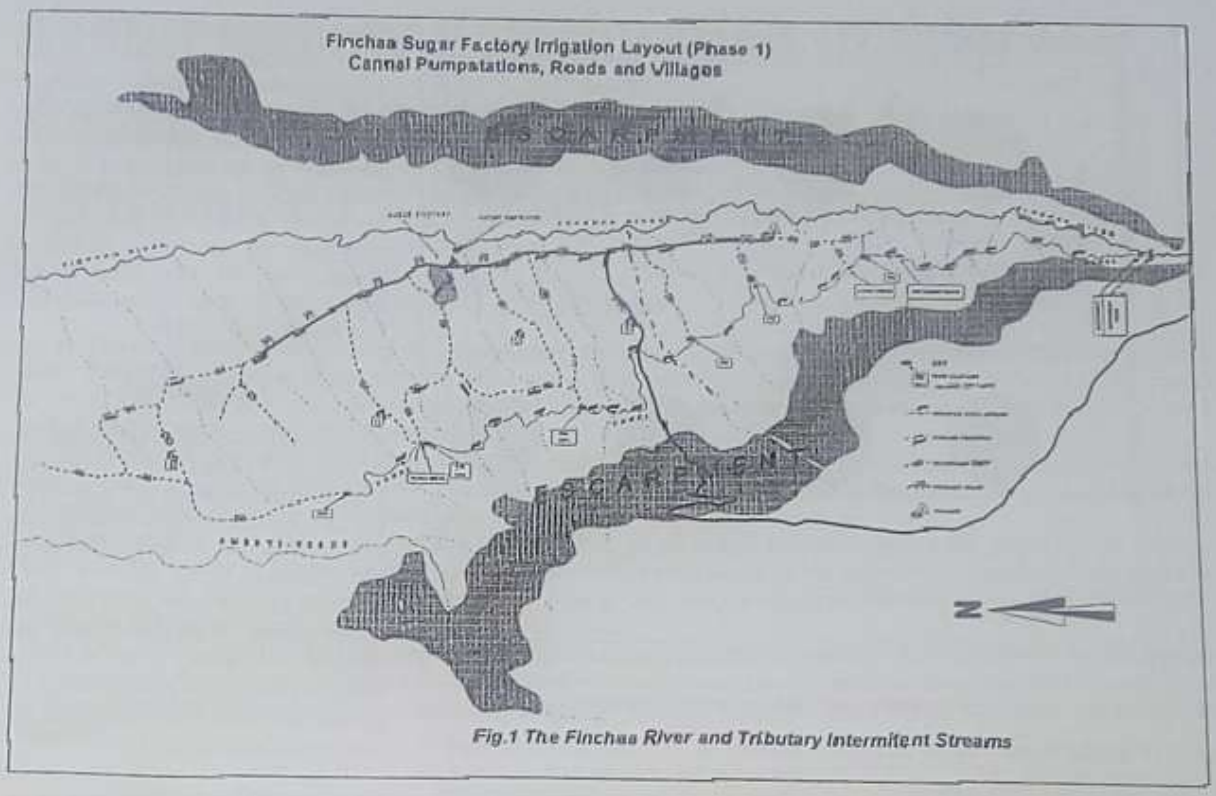

Fig.1 The Finchaa River and Tributary Intermitent Streams

The conveyance system consists of diversion weir, canal, inverted siphons and head control structures. Consequently the water is distributed up to the edges of the cane fields using asbestos cement pipes which are laid under ground. The flow of water into the pipes is regulated using various types of isolating valves. Besides pressure regulating valves are also installed to reduce the down stream pressure in places where the pressure exceeds the maximum design pressure.

The most prominent part of the Finchaa Sugar Factory irrigation system is the use of sprinklers for irrigation water application to the cane fields for about 6800 ha. The use of sprinklers in such a large scale made the Finchaa Sugar irrigation system unique since it is the only place in the country where sprinklers are applicable in a large scale.

3.1 Design consideration

- The parameters and procedures that have been considered in designing the irrigation system can be categorised into three major groups.

- The canal, siphons and the head control structure being the conveyance system in one group;

- The network of pipes and flow regulating valves being the distribution system in the second group and

- The laterals and sprinklers being the application system in the third group.

Since the parameters used for the hydraulic design of the canal are not unique and are similar to other canals, emphasis is given only for the second and third categories.

Design of the piping network

The main aspects of sprinkler irrigation system is its ability to apply water in the form of drops or sprays similar to rains. This is only possible when the water is pressurised and allowed to escape through small openings or nozzles which are specially made to facilitate the application.

In most places the operating pressure is created using pumps which consume a large amount of energy, be it diesel or electric (Stout 1979 and FAO 1968).

Here at Finchaa, the unique features of the land terrain have given the opportunity to make use of gravity energy to create pressure in about 65% of the estate for operating sprinklers without pumps, thus reducing the energy cost which is one of the major components of the operating cost. Therefore, the piping network is designed in such a way that the pressure remains at the range of 4.5 to 10 bars.

This is achieved by selection of the correct pipe sizes and by using pressure reducing valves where the pressure exceeds more than 10 bars. Moreover isolating valves are provided at every branching pipe lines and at various length of the main pipe line for enabling maintenance without shutting down the whole system. Also provided are air valves at the peaks and drain valves at the depressions along the alignments of the pipeline.

Design of the sprinkler system

The method of irrigation application is by the use of drag-line sprinklers with a 36m long flexible hoses which are connected to the lateral pipes with a quick couplings. The lateral pipes are spaced at a distance of 90m and the po-

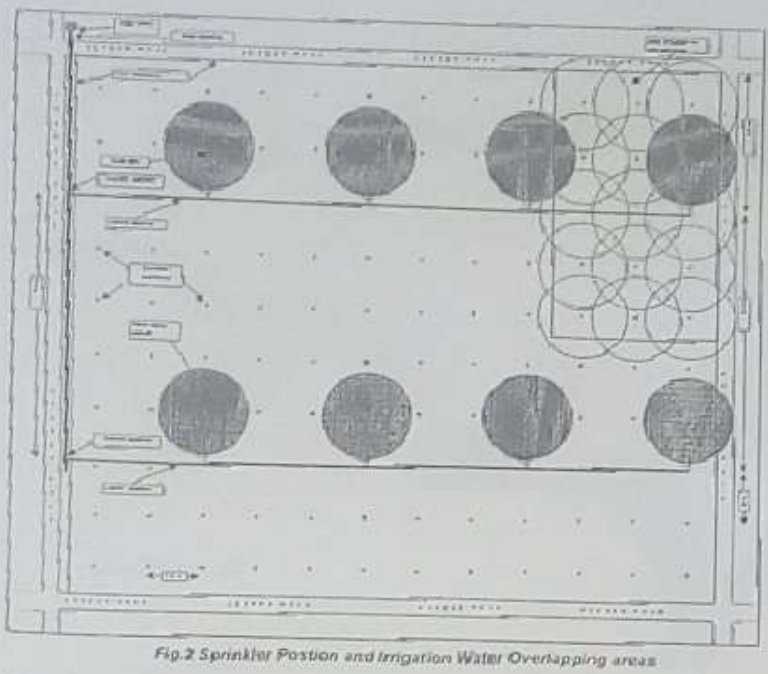

Fig.2 Sprinkler Postion and Irrigation Water Overlapping areas

sition of sprinklers are made to be at 18 meters apart (see Fig. 2).

Therefore, the sprinklers were selected using the manufactures data to provide a gross irrigation application of 5.6 mm/h for a grid of 18m by 18m area. With such a design the maximum area that would be irrigated by one sprinkler is 0.486 ha so that the number of sprinklers required for a 100 ha of field is not less than 205 in number.

The laterals are designed to follow the cane rows which are made at a declining slope from the hydrant, but not more than 3%. The maximum length of the laterals are designed to be not more than 540m so that the variation in the nozzle discharge and operating pressure would be with in the allowable limit of not more than 10% and 20% respectively (Merriam et. al. 1983 and Merriam and Keller 1978).

The pressure at the hydrant is regulated to be 4.5 bars using a hydrant valve which enables the mean operating pressure at the nozzle to remain at 3.17 bars after deducting all the frictional head loss from the laterals, the hoses and the riser pipes. This allows a gross irrigation application of 134.5 mm/day for a 24 hours set-time at a 15 days cycle during peak water requirement periods. Using an application efficiency of 75% this allows to apply a net irrigation of about 100 mm/15 days which is near to the maximum evapotranspiration of sugar cane at the peak periods.

3.2 Management considerations

The sprinkler irrigation system enables a higher operational flexibility and uniformity of water application. When the sprinklers are powered by gravity, with out pumps, the degree of flexibility is much higher such that operation is not interrupted when there is power failure or downtime of pumps.

Once the underground pipes and the in-field irrigation pipes are installed, the remaining operational tasks are easily performed. The sprinklers are shifted/moved from one position to the next position every day or twice a day depending on the requirement.

With the current condition, 50 sprinklers together with their riser pipes and hoses are moved by one person per day. When the sprinkler movers gain experience and the piece rate payment becomes attractive it is believed that the productivity rate of a person will be doubled. Thus a person can be able to irrigate about 45 ha.

The main problems observed in operating the sprinkler irrigation are frequent blockage of nozzles by debris and other foreign materials which are brought with the irrigation water through the canal. Therefore close supervision by the irrigators is of paramount importance. Wind also affects the pattern of the sprays disturbing the uniformity of distribution so that in places where the wind speed is at a higher rate the drag-line sprinkler system may be undesirable.

4. Conclusion

The general topography and the soils of the Finchaa Valley have given a favourable condition for implementing an irrigation system using the energy from gravity to operate the sprinklers. Ethiopia being endowed with a vast area of land suitable for irrigation and a number of perennial rivers and streams, originating from the highlands with sufficient gradient along the course, has enormous potential to operate sprinklers by gravity.

It is, therefore, worth considering the potential rivers and streams for irrigation by sprinklers with the fact that, unlike furrow irrigation system, the undulating topography of the land does not prohibit its implementation.

However it should always be noticed that any irrigation development has to be planned, designed and implemented based on the prevailing conditions of that locality since the ultimate objectives are to realise the highest returns from the investment.

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Water quality deterioration in micro-dams; is it becoming a threat for sustainable irrigated agriculture?

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Abstract

In Tigray, in an effort to curb-up the severe water shortage, various attempts have been made to promote surface water harvesting by means of micro-dams. So far about 50 micro-dams have been constructed and another 450 are yet to come. The Gumselasa micro-dam is one of these dams which is constructed five years ago and currently it is faced with a sudden water quality deterioration.

The basis of this study is, therefore, the sudden change of the water-colour from normal blue green into deep red/brown within a period of three months. The objective was to identify the source of this colour change and to find out the impact of this incidence on the suitability of the water for irrigation purposes.

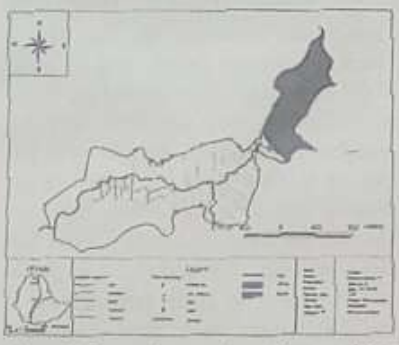
Water samples were taken for analyses and chemical, physical and biological tests were performed in order to determine the source of the colour. Biological structures that were found in the water were identified to be the cause of the colouring. Determination by means of laboratory tests and literature studies has shown that the biological structures are myxobacteria from the Polyangiaceae genus.

In order to see the effects of these bacteria on the chemical properties of water and on crop performance, analysis was done on relevant characteristics and it was found-out that there were no negative effects that could be attributed to these biological structures. Hence, the water is still suitable for irrigation and crop performance and yield is not affected

Introduction

Since Tigray suffers from long dry periods and short raining periods the distribution of water is unequally divided throughout the year. To perform high yield agricultural crop production water harvesting is necessary. Water harvesting by means of micro-dams is one of the strategies to cover the water deficit in crop production in Tigray.

The Gumselasa micro-dam is one of the dams in the southern parts of Tigray, which is constructed to irrigate a command area of 110 ha (Map1). The construction of this micro-dam was in 1996, and as of the year 1997 it was functional.



Map 1. Gumselasa micro-dam and its command area

In December 2000, a slight colour change of the water within the reservoir of this micro-dam was noted. In April 2001, the colour of the water changed so much that research to the source of this colour change became necessary.

In order to see the extent and severity of the incidence, visual analyses were done around the micro-dam, and the results were that the colour of the water within the reservoir of the Gumselasa micro-dam was homogeneously red/brown seemed to be caused by a red/brown substance suspended in the water. Also in the main and secondary canals, the irrigation water had this strange colour. The substance covered the entire reservoir but it was not exactly clear how deep this colouring went. Since the water in the outlet canal was also reddish and the water was taken from a deep point it can be assumed that at least the entire water body, which is used for irrigation purposes, is covered with this substance.

Hence, the major objectives of this study are:

- To identify the substance that caused the colour change.
- To find out whether the water is still suitable for irrigation.
- To find out whether this strange incidence affects the crop performance and yield.

To meet the above objectives, the following research questions were formulated:

- Is the colour of the water caused by a chemical, physical or biological contaminant?
- What is the exact nature of the contaminant found?
- What can be done to treat or to prevent contamination?
- Is it possible that this contaminant also affects other micro-dams in this region?
- How can the primary goal (obtain food security) of the construction of

Map 2. Map of Ethiopia

Map 3. Map of Tigray

Map 3: location of Gumselasa micro-dam

these micro-dams be maintained with regards to water quality?

· Is this the first time that open water gets contaminated with these structures?

Site Description

The micro-dam of Gumselasa is located in the southern administrative zone of Tigray, 4 km east of the village Adigudum. The geographical location of the experimental site is at 13°14' N and 39°32' E at an altitude of about 1960-meter above sea level. Map one and two below are maps of Ethiopia and Tigray.

Map three is a map on which the position of the Gumselasa micro-dam is marked in relation to Adigudum.

The maximum capacity of the reservoir of the micro-dam is 1.902.000 m^3. This is sufficient to provide a command area of 110 ha of irrigation water. The area belongs to the 'Weyana Dega' agro-ecological zone. This is the traditional classification unit from the agro-ecological categorizing in the region. It is characterized by an average temperature ranging 16° up to 20°C. The rainfall is between 300 mm and 900 mm per year (HTS, 1975). Since the rainfall is highly variable within and between the years and its erosive impact is high, the area is characterized by a lot of land degradation. This land degradation is enhanced by a long history of overgrazing and over cultivation as a result of high population density and low agricultural productivity.

The two major soil types that you can encounter in the irrigated area are according to FAO classification vertisols (61%), Luvisols (18%), Cambisol (4%) and regosols (4%). This year the command area of the Gumselasa micro-dam extends to 79.9ha. On this surface, 349 farmers are cultivating crops. The major crops that are grown are maize, onion, tomato and potato. The production of these cash crops is of great importance for the region.

Materials and methods

Materials

To perform the physical tests turbidity meter, photometer and centrifuge were used. For biological tests microscope and accessories, incubator and accessories, agar and minerals, photograph-microscope, balance oven were used. For the chemical analyses titration device, photometer, flame-photometer (sodium and potassium), quick tests for determination of elements in the field, pH-meter and EC-meter were used.

Method

Water samples were taken from the micro-dam of Gumselasa. Annex 2 is a schematically drawn map of the reservoir from which samples were taken. After four days, samples were filtered with standard filter paper. After filtration the colour was measured with a photometer. For microscopic examination, slides were prepared and observation was done at different magnifications, drawings of the structures found were made. For other relevant quality parameters, analyses were done following standard procedures.

For the identification of the biological structures,different agar media were prepared i.e. CT agar and starch agar for myxobacteria,medium BG11 for cyano bacteria, and mix of trace metal were prepared (1). After the preparation, the media were inoculated with the structures in a sterile environment. To sterilise the environment a 70% alcohol solution and a gas burner were used. To minimise the chance of contamination with bacteria's from the air, the windows and doors of the room were the inoculation took place were closed. After inoculation some petri-dishes were closed and put in an incubator while other petri-dishes were put in the laminar air flow. The reason for this was to check whether the organisms were photosynthetic or not.

To separate colonies of the micro-organisms they were over-inoculated after 4 days to new media. This was done to prevent mixing up the different types of micro-organisms that were present on the media. At the same time a media was prepared from the water of the Gumselasa micro-dam. The water was filtered and autoclaved. After cooling down some of the structures were inoculated in the media.

For comparison with common soil micro-organisms cow dung was collected. Preparations of it were made and they were studied with the microscope. Cow dung was also used as basic ingredient of an agar medium. Cow dung was added to a mixture of water and agar. It was put into petri-dishes and was autoclaved for 15 minutes at 121°C. After cooling down until room temperature, the material collected from the water samples were inoculated on the medium. After inoculation the petri-dishes were put in the incubator at room temperature in the dark.

At the end of the growing periods all the petri-dishes were studied with a microscope to be classified. Photographs of microscopic views at different magnification were made in order to compare with literature information.

The classification was done by determination by using the Soil Microbiology Guide (Dindal, 1990). To crosscheck literature in practise a "mini Gumselasa pond" was created. Dead algae was collected and put into a petri-dish. It was sterilized and the structures from fresh sample were put out on it. One week after inoculation filtered and sterilized water from the Gumselasa micro-dam was poured into the petri-dish. The mixture was put in the incubator at room temperature in the dark. Every week "mini Gumselasa pond" was observed.

To evaluate the suitability of the

Gumselasa micro-dam water for irrigation purposes, chemical analyses of the water were done. Most of the elemental analyses of the water were done in duplicate. First the analyses were done in the field; pH and EC were measured at different dates and spots. Each pH and EC measurement was done ten times to get a representative value. Quicktests were made on some soluble minerals. Other relevant elemental tests were made in the laboratory.

Results and discussion

Identification of the source of the colour

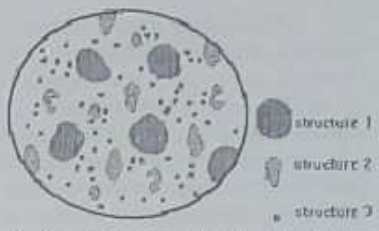
The study has shown that a biological material, which is suspended throughout the water, causes the red/brown colour of the water within the micro-dam of Gumselasa. This conclusion was drawn based on the following findings.

When the samples were stored for a few days something remarkable happens. A red/brown film was visible on the top of the samples while the rest of the water has turned colourless. When you touch the samples slightly this film breaks down and the water turns red/brown again. This indicates that the substance, which colours the water, is probably lighter than the water. So, to make concentrated samples for further observations centrifuging was used. After filtering the water-samples a red residue remained at the filter. The colour of the filtrate was measured and the result was a colour of 0 PtCo (Platinum & Cobalt as indicator). This means that the colour of the filtrate has 0 % difference with filtered distilled water. In other words the water is colourless so now we can conclude that the red substance that remained at the filter causes the red/brown colour of the water.

The first microscopic analyses of the preparations gave us the following results:

Findings at 40 times magnification:
The floating substance consists of three different kind structures:

- Small light brown conglomerated round structures, which form closed surfaces.
- Medium dark brown conglomerates with often a hole inside.



Picture 1: microscopic view at 40 times magnification

- Big black balls, which are moving through the water in preparation. They never mix with each other and also not with the two other structures. They seem to consist of smaller sub-parts.

Structure	Size	Colour
1	1 times	Light-brown
2	5 times	Dark-brown
3	7.5 times	Red-brown

Table 1: colour and size of the structures

The picture one is a schematic drawing of the microscopic view of the concentrated sample.

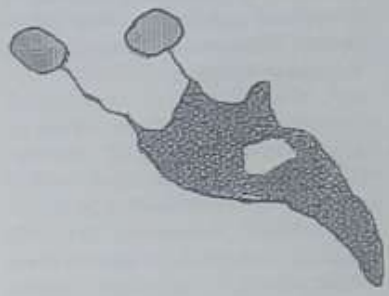
Findings at 100 times magnification
At this Magnification the differences in sizes are visible. From the table below we can read the differences in size and colour between the different structures.

Findings at 400 times magnified
The structures 1 and 2 seem to build up the same way as structure 3. It even seemed that all structures are the same with only differences in size. Methyl-blue was used and the structures were studied once more under the microscope. Methyl-blue colours the cells from inside. The different cell parts then became visible. The result was

Picture 2: schematic drawing of structure 3

that the entire structures adsorbed the blue dye and no differences became visible. Picture two is a schematic drawing of structure 3.

The colour of structure 3 at this magnification is somewhere between yellow and brown and the size of the structures varies. There are differences in behaviour found within the preparation, structure 1 and 2 stick together and form colonies while structure 3 is moving and mixing.



Picture 3: dried sample at 100 times magnified

Since the preparations were made from the substance in water the preparations were dried out after about 30 minutes. Observation of the dried sample showed us that the structures shrink when they become dry. The picture on the next page is a schematic drawing a part of a dried slide at 100 times magnification.

In order to prove the origin of the biological material, the following tests were made with the following results:
Soil test: One of the ideas was that the structure might be organic compound, so these structures have to be present in soil also. In the soil sample, structures were found which had the same morphological appearance as structure 3.
Peroxide test: After adding peroxide to the sample a slight reaction was visible. Small air bubbles appeared in the mixture and with microscopic observation after 30 minutes a difference was notable. Structure one had totally disappeared and structure two had decreased in amount enormously. Structure three was still present; the only change noted was that some of the structures had lost their colour and became white. Observation of the sample after five days revealed that the red colour has totally disappeared and it is replaced by a white conglomerated structure, which is suspended through

the solution as a white snow.

Boiling test: While heating the sample the structures were burned out. First the structure seemed to fall apart and afterwards it went to the top of the jar in the form of bubbles. The water became totally clear after boiling.

Balance oven test: After heating the structure at 60°C for 2.5 hours, structure one had disappeared. The other structures remained completely intact.

Related study on the same subject showed that there are four categories of biological structures.

· ***Organic compound or faeces:*** according to McSweeney & Fastovsky (1990) mention *iron oxide stained spherules of possible biological origin.* These enigmatic hematite spherules, interpreted to represent iron oxides associated with organic matter. Modern examples involving bacterial mobilisation of ferric oxyhydroxides exist. The unusual external spherulic morphology may be attributable to the soil microbiota, or it may represent pseudomorphs after other biological features such as pollen.

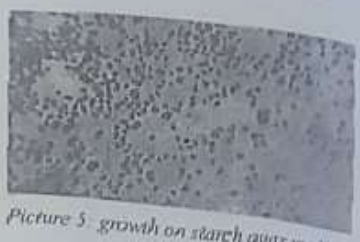
· ***Algae:*** Stanier et al (1987) mention the cyanobacteria, which were formerly known, as the blcu/green algae are a diverse assemblage of Gram-negative eubacteria characterised by their ability to perform oxygenic photosynthesis. Many cyanobacteria are obligate photoautotrophs, being wholly incapable of dark growth without the presence of organic sources of carbon and energy. The chemotrophic growth rate of those strains that can grow in the dark is very low relative to that in the light; it occurs only at the expense of glucose and a few other sugars, which are dissimilated by aerobic respiration. The Pleurocapsa group is a group of cyanobacteria that is distinguished by a mode of reproduction that is rarely encountered among other bacteria: multiple fission. Multiple fission is a series of successive binary fission's without intervening cell growth; hence the cell undergrowing this mode of division is cleaved into a number of daughter cells, termed Baeocytes, that are much smaller daughter cells then the mother cell. Baeocytes may be motile; if so they lose their motility before commencing growth. Most members of the Pleurocapsa group are facultative chemohetrotrophs. They are wide spread in soil or in fresh and salt water. The structures found in the samples had strong resemblance with the morphological appearance of the specific species of the Pleurocapsa group namely; *Myxosarcina.*

· ***Bacteria:*** Stanier et al (1987) mentions that Myxobacteria are gliding chemohetrotrophs with a unicellular morphology. Myxobacteria are soil organisms and are usually detected in nature through development of their fruiting bodies on solid substrates: bark of trees, decomposing plant material and dung of animals.

A few species of the Myxobacteria, all of the genuses Polyangium have prominent nutrient requirements. They are active cellulose decomposers and grow in a medium with a mineral base, supplement either with cellulose or with hydrolytic products. Since the morphology of the structures found in the samples showed strong resemblance with the physical appearance of certain species of the Polyangium genus further research on this micro-organism was performed and it was confirmed that it belongs to the above-mentioned genus. Picture four is photo from the literature, which was taken from microscopic view at 573 times magnification.

Picture four: Polyangium sp, at 573 times magnification.

Some more peculiarities of these bacteria are, they did not grow on media BG 11. The structure remained totally intact on the media and no significant growth was found. Some explanations for this finding can be that the environment was not suitable for this type of organism or the growth



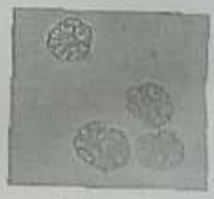
Picture 5 growth on starch agar medium

was to small to be noted.

On the starch media, growth was found under dark conditions. One can conclude that this living organism is not photosynthetic unlike the cyanobacteria, which are photosynthetic. A picture taken from growth on starch agar medium that was taken at 40 times magnification is shown (picture five).

The myxobacteria show a lot of environmental and physical resemblance with the cyanobacteria. The results on agar media showed us some interesting facts. The structures grow fast on the starch agar media but not on the CT agar media. The growth on the starch agar was long time undetectable but after about four weeks exponential growth was noted. To crosscheck whether the structures found in the water of Adigudum are the same as the structures grown on agar, photographs of both structures were compared. Picture six is a photograph taken from structures present in water of the Gumselasa micro-dam and picture seven is a photograph taken from structures, which have been grown on starch agar. Both photographs were taken at 400 times magnification. The conclusion that was drawn was that both structures have the same morphology and are most likely the same.

Picture 6



Picture 7

From literature there was derived that myxobacteria occur in dung of animals, so animal dung was collected and studied. Microscopic analyse from dung samples showed us that exactly the same structures that were found in the water-samples were also present in the dung.

It also seemed that a dung-agar medium is a good medium for the structures to grow on. Further research of the colonies formed on the dung agar showed us that the behaviour from the structures in water was totally different from the behaviour on a solid cellulose rich medium. The structures are smaller on the dung and the form rods and groups. The structures were identified to be fruiting bodies of a chemotrophic organism.

Since we now know that the organism is chemotrofic (it grows in the dark) and it consumes organic material (lives on dung), it can be concluded that the structure is chemoorganotrophic. As Stanier et al (1987) mention cells of the myxobacteria are capable of gliding when they are in direct contact with other cells. They can move with a speed of 1 up to 150 mm per minute. They can also move singly, however this cannot be sustained for long. Periodic contact with other cells seems to be necessary for continued movement.

So it can be assumed that these cells are capable of gliding (otherwise they could not have formed colonies and rods on the (dung)-agar medium) and comparison with literature showed us that the structures found are most probably fruiting bodies. Microscopic analysis has shown that the physical appearances of the structures are spherules that sometimes form rods or colonies, so the vegetative cells have blunt ends (rounded).

The structures found in the water samples are most probably the fruiting bodies of myxobacteria from the Polyangiaceae genus.

To substantiate this finding the following arguments can be used:

- The structures are living organisms.
- The structures are not photosynthetic.
- The structures grow on starch agar.
- The structures have the same morphology as fruiting bodies from myxobacteria from the Polyangiaceae genus.
- The structures have the same morphology as the structures found on cow dung.
- The structures are capable of multiplying in water environment.
- On solid media the structures form colonies.
- In dry conditions the structures form rods in which the different cells are not distinguishable.

After thoroughly understanding the causes of the water quality deterioration, there was an attempt to investigate whether this bacteria affects the suitability of the water for irrigation use. Until now no negative impact of the biological structure was found. Crop performance and yield was unaffected. literature also does not mention any negative influence of bacteria of the Polyangiaceae genus on crop yield or quality.

Since animals and even human make use of the water from the micro-dam for drinking purposes and as far as known no injuries were reported, there can even be assumed that drinking of the water gives no problems at short term. What has to be noted is that water with a turbidity of more then 25 NTU is not suitable for drinking purposes (standards of Bureau of Water Energy and Mines). Since the turbidity of the water within the micro-dam of Gumselasa is 165 NTU this water is classified as unsuitable for drinking. Filtering water from the reservoir of Gumselasa makes it suitable for drinking.

The pH of the water was rather high (most recent measurement; an average of pH 8.77 at 24.1 °C). Although the pH was high it has probably no significant effect on negative effect on plant growth. The EC of the water was not different from the other years. The crops that are grown in the irrigated area perform well when they are irrigated with water with an EC value of about 244 ms/cm. Some other relevant properties, which were analysed, are listed in table 2:

Parameter	Quickteste mg/l	Laboratory mg/l
Total hardness as CaCO3	90	117*
Calcium hardness as CaCO3		86*
Magnesium hardness as CaCO3		31*
Total alkalinity as CaCO3		84*
Bicarbonate alkalinity as CaCO3		84*
Carbonate alkalinity as CaCO3		0*
Hydroxyl alkalinity as CaCO3		0*
Sodium		13.9**
Potassium		4.0**
Bicarbonate		115*
Nitrate	3	8.6***
Nitrite	0.009	
Calcium		34***
Ammonium	0	
Chloride	120	137***
Phosphate	0.35	0.37***
Iron (total)	0.5	0.53***
Copper		1.01***
Magnesium		7.44***
Sulphate		25***

* Measurement done by means of titration
** Measurement done by means of flame photometer
*** Measurement done by means of photometer

Table 2: outcome of the elemental tests

From the above values one can conclude that the water is suitable for irrigation considering the elements that were tested only the amount of chlorine was rather high. A concentration of chlorine above 140 mg/l can affect plants, which are sensitive for chlorine.

The standard procedure for the classification of water for irrigation purposes is done by means of the "Diagram for classification of irrigation waters". The EC and the SAR (Sodium Adsorption Ratio) can be entered in this diagram and then the suitability of the water can be read. This method is used to measure the sodium hazard. If there is too much sodium compared to calcium and magnesium, sodium will replace calcium and magnesium in the soil. This will result in limitations in plant growth due to less favourable physical and chemical properties in the soil.

The SAR of the water can be calculated with the following formula:

$$SAR = \frac{[Na+]}{\sqrt{\frac{[CA2+] + Mg2+]}{2}}}$$

(The concentration is expressed in milli-equivalent per litre.)

So the SAR value of the water within the reservoir of the Gumselasa micro-dam is 0.56. If we fill in the results from the SAR and EC measurements in the diagram for classification of irrigation waters (annex 6) there can be concluded that the water is suitable for irrigation of soils.

Conclusions and Recommendations

The cause of the change in watercolour of the reservoir of Gumselasa micro-dam is biological. High amounts granular shaped spherules with an average size of about 10mm with a red/brown pigment are suspended through the water. The biological structures are most likely fruiting bodies from myxobacteria's from the Polyangiaceae genus.

The myxobacteria from the Polyangiaceae genus are mainly active

cellulose decomposers. This means they feed themselves on decomposing plant material and in some cases they are capable in killing small micro-organisms by secreting antibiotics. They occur widely spread in soil (and water) and are capable to form fruiting bodies, which can survive long time under unfavourable conditions.

No direct effect of the bacteria's on plant growth was found so we assume that the water within the micro-dam of Gumselasa is still suitable for irrigation purposes with regards to the presence of the myxobacteria.

The chemical properties that were measured showed us that the water is suitable for irrigation and that sodium hazard in the soil will not occur if the irrigation is managed properly.

When the decision is made to treat the bacteria's the method should be well considered. Chemical treatment, emptying the reservoir or a combination of these two methods is possible. Since the bacteria's are common in the soil it will probably have no long-term solution, because they will return back to the reservoir and when the conditions are favourable they will probably grow exponentially again.

To come up with a definitive solution, a thorough study to the biological balance in these schemes becomes mandatory. When a biological balance in these lakes can be created there will be less problems of extreme growth of bacteria, because natural enemies and food shortage will repress growth.

Acknowledgements

The authors would like to express gratitude to the employees of the Bureau of Agriculture of the Adigudum district for their contribution during the fieldwork. Thanks are also due to the employees from the Bureau of water, energy and mines and all colleagues from Mekelle University who contributed in this research by means of providing equipment, assistance or information.

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The Effect of Antecedent Moisture Content on the Infiltration Patterns of Dryland Vertisols

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Abstract

This paper describes the infiltration rate and its relationship with the antecedent soil moisture content in Typic Haplusterts (Vertisols) of Southern Tigray. A field experiment was carried out to investigate the infiltration pattern for the purpose of introducing cost-effective and sustainable small-scale irrigation systems. The measured data were analysed for cumulative infiltration, instantaneous infiltration rate and average infiltration rate. Philip's equation and ANOVA were used to analyse and interpret the data. Generally, this study proves that for the dryland Vertisol the antecedent soil moisture content affects the infiltration patterns of the soil.

Introduction

Vertisols, which are generally regarded as inherently fertile and potentially productive, are the fourth most important soil order in Ethiopia, after Lithosols, Cambisols and Nitosols. Vertisols comprise 10.3 percent or 12.6 million hectare of the Ethiopian landmass (Jutzi and Abebe, 1986). These soils are especially important in the Ethiopian Highlands where they cover 24 Percent of all soils cropped (Woldeab, 1988).

In the Ethiopian Highlands due to adequate and predictable rainfall, several food crops such as teff, wheat, finger millet, horse bean, lentil, chickpea, field pea, nuog and sesame are produced in developed cropping systems which take into account the adaptability of some crops to excessive soil moisture during the wet season and the ability of others to be productive on stored soil water. But in dryland Ethiopia, where the coverage of Vertisols extended up to 5 million hectares, the rainfall distribution is inadequate and unpredictable. In such areas, under rainfed conditions, crop yields and productivity are low. It is therefore of great importance to undertake a research for soils in the dryland to improve the soil water storage and moisture use efficiency.

To significantly improve the water use efficiency, "in situ" knowledge of physical and hydrodynamic properties of Vertisols is of paramount importance. It allows to estimate, at any moment, the possible water losses through evapotranspiration and drainage, runoff and changes in available water storage under specific climatic conditions. Studies on the infiltration of vertisols are the overriding theme of this paper.

This research was conducted with the objective of understanding the infiltration hydrodynamic property of vertisol in the Gum Selasa, Tigray through measuring the infiltration rate of the soil at different initial soil moisture levels in the field. The information generated is important for use when predicting water flow in natural profiles of a swelling clay soil.

What is infiltration?

Landon (1991:59) defines infiltration as "... the vertical intake of water into a soil, usually at the soil surface..." the manner in which water infiltration into the soil is described by the Green-Ampt theory in Kulute (1986). The theory explains that water advances downward in the soil as piston flow, which is with uniform hydraulic conductivity in the wetted zone and with a constant pressure head of water at the wetting front. Kulute (1986:826) applied Darcy's equation to the flow system and found:

$$Vi = Kw (Hw + Lf - hf)/ Lf$$

where: Vi = infiltration rate (length/time).

Kw = hydraulic conductivity of wetted zone (length/ time).

Hw = water depth above soil

hf = pressure head of water at wetting front, and

Lf = depth of wetting front.

This shows that the infiltration rate is directly proportional to the hydraulic conductivity of the soil, the depth of water above the soil and the difference between the wetting front and the pressure head of water at the wetting front, and inversely proportional to the depth of the wetting front. The hydraulic conductivity of the soil is itself dependent on several factors like the soil structure, texture, moisture content, and fluid viscosity (Landon 1991, Kulute 1986).

The rates and amounts of water that enter a soil known to provide indications of the magnitudes of the amount of water input into a soil, the extent of runoff, and erosion hazards, depth of the leaching and the contribution o each water supply into the stored soil moisture (Hillel, 1980). Soil infiltration rates depend on initial soil moisture condition, soil texture, structure and aspects of land. In vertisols, infiltration rates depend on the presence and absence of cracks, extension of cracks to the surface and presence or absence of the self-mulching characteristic (Dudal, 1965).

Material and Methods

Site description

Gum Sellasa micro-dam is located at the southern edge of Adigudem town, southern Tigray, which is 35 Km from Mekelle on the road to Addis Ababa. The dam was constructed across a river to harvest water for the purpose of irrigating the surrounding.

The command area of the dam is 110 hectare. The soil in the command area is predominantly vertisol and followed by Inceptisols and Entisols. The rainfall of the area has a bimodal distribution with an average of 700 mm of rain per year. The crops grown in the irrigated fields are onions, maize and tomatoes, while in the rain fed fields wheat, barley, maize and sorghum are grown. The irrigated fields show signs of salinisation especially in the dry season. The physical evidence of salinisation shows that the salts present are saline-sodic.

Methods

The double ring method was used to study the infiltration rates in this study. Vertically two concentric metallic rings (inner 30-cm diameter, outer 60-cm diameter, heights 50 cm) were pushed about 15 cm into the wet soil so that the smaller ring is centred in the larger. Both cylinders were filled with water to about 15 cm, after that time and distance from the water level were recorded in the inner cylinder to the inner cylinder top. Then the water levels were measured at 1, 5, 10, 20, 30, 45, 60, 90 and 120 min. Once the water was fallen to a certain level, the rings were filled to the original level and the fall in water was measured again. In this manner measurements were made until the rate at which the water falls reached a constant, which took 3 to 5 hours (Landon 1991). Besides, the soil moisture content at different depths, i.e. 0-15 cm, 15-30 cm, 30-60 cm, and 60 90 cm were determined gravimetrically to observe the relationship to the infiltration rate.

Data Analysis

The data obtained by measuring the rate at which the water enters the soil can be analysed in different forms. According to Landon (1991) there are four ways of handling infiltration data, which are: the cumulative infiltration, the instantaneous infiltration, the average infiltration and the Philip's equation. The cumulative infiltration is the quantity measured in the field as plotted with time and cumulative depth (Ibid.). The instantaneous infiltration is the slope of the graph of the cumulative infiltration. The average infiltration is "...the cumulative infiltration divided by the time from the start of infiltration." (Ibid.: 65). The Philip's equation is given by:

$F = at^{0.5} + bt$

Where: t - is time

F- is cumulative depth

a - is sorptivity of the soil

b- is the hydraulic conductivity

As can be seen the sorptivity and hydraulic conductivity need to be known to use the equation. To find out the values for 'a' and 'b' the equation is first modified as:-

$F/t = at^{-0.5}/t + bt/t$, which will give

$i = 0.5\ at^{-0.5} + b$, where i is the instantaneous infiltration rate.

By taking the log of 'i' and log of 't', a regression analysis is done to give equations relating them and showing the values of 'a' and 'b'.

The initial soil moisture content of the samples is determined using the gravimetric method as described in Landon (1991:84) by the formula:

$Mc = \{(Ww - Ow)/ Ww\} * 100\%$

Where:

Mc - the moisture content

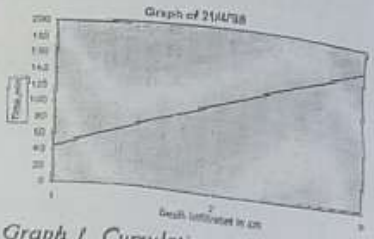
Ww - weight of the wet sample

Ow - weight of the oven dried sample

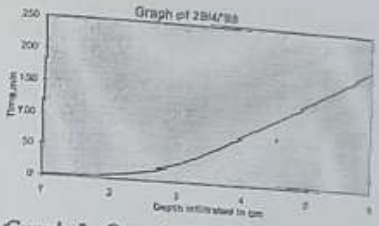
Results and Discussion

The results of the average of the triplicate infiltrometer measurements and the corresponding soil moisture obtained are presented in Table 1.

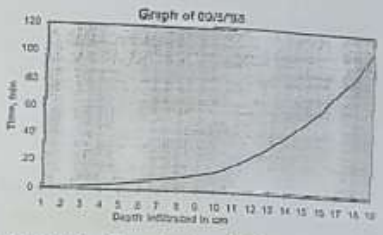
The data of the cumulative time and depth was plotted to the cumulative curves and the instantaneous infiltration rate, which is the slope of the curves. The plotted graphs are shown in graph 1 to 5.



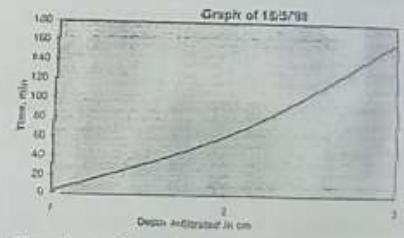
Graph 1. Cumulative infiltration graph for the date 21/4/'98



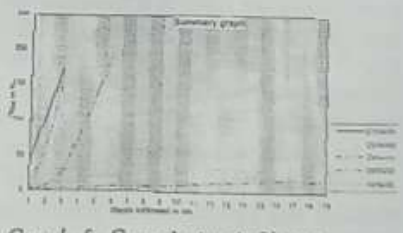
Graph 2. Cumulative infiltration graph for the date 29/4/'98



Graph 3. Cumulative infiltration graph for the date 09/5/'98



Graph 4. Cumulative infiltration graph for the date 18/5/'98



Graph 5. Cumulative infiltration graph for all the dates.

Table 1. Averages of the triplicate infiltrometer a measurement.

From the cumulative infiltration curves above, the constant hydraulic conductivity is reached when the instantaneous infiltration rate, i.e. the slope is at its gentlest. The infiltration rate at this point is known to be the infiltration rate at the saturated hydraulic conductivity (Landon 1991) which is around 1.6 cm/hour. According to Landon (1991:69-70) the infiltration rate is moderately slow and optimum for irrigated crop management provided other factors are also suitable.

The average infiltration rates for each day is given in Table 2.

Date	Average infiltration rate in cm/ hour	Average initial soil moisture level in % by weight
21/4/'98	01.04	24.06
25/4/'98	01.78	18.28
29/4/'98	01.86	23.27
09/5/'98	10.42	19.70
18/5/'98	01.12	23.25

Table 2. Average infiltration and average moisture contents.

Using the modified Philip's equation, the log of 'i' and log of 't' were calculated and fitted into a regression equation to give equations representing the sorptivity and hydraulic conductivity values. The results of the log calculations are given in Table 3.

To check weather there was any significant variation in the infiltration data as a result of the change in the soil moisture content, a one way ANOVA was done because the factors influencing the infiltration were not controlled enough to make an interaction analysis with the moisture level and infiltration. The results of the ANOVA are given in Table 4.

Date	'i'	't'	log of 'i'	log of 't'
21/4/'98	0.022	0.149	-1.653	-0.827
	0.016	0.128	-1.789	-0.894
	0.015	0.123	-1.823	-0.911
25/4/'98	0.077	0.277	-1.114	-0.557
	0.032	0.180	-1.490	-0.745
	0.021	0.146	-1.673	-0.837
	0.023	0.151	-1.640	-0.820
29/4/'98	0.333	0.577	-0.477	-0.238
	0.303	0.550	-0.519	-0.259
	0.046	0.215	-1.334	-0.667
	0.019	0.140	-1.710	-0.855
	0.018	0.135	-1.740	-0.870
	0.017	0.129	-1.770	-0.880
09/5/'98	1.250	1.118	0.097	0.048
	1.111	1.054	0.046	0.023
	1.000	1.000	0.000	0.000
	0.769	0.877	-0.114	-0.057
	0.714	0.845	-0.146	-0.073
	0.455	0.674	-0.342	-0.171
	0.370	0.609	-0.431	-0.216
	0.181	0.426	-0.740	-0.370
	0.154	0.392	-0.813	-0.406
	0.132	0.363	-0.881	-0.440
	0.108	0.328	-0.968	-0.484
	0.098	0.313	-1.009	-0.504
	0.092	0.303	-1.037	-0.519
	0.078	0.278	-1.111	-0.555
	0.076	0.276	-1.117	-0.559
	0.051	0.226	-1.292	-0.646
18/5/'98	0.313	0.559	-0.505	-0.253
	0.017	0.130	-1.773	-0.888
	0.010	0.101	-1.992	-0.996

Table 3. Log values of 'i' and 't'.

Source of variance	Sum of squares	Degrees of freedom	Mean square	F-ratio	F tabulated	
					5%	1%
Between groups	[illegible]	4	[illegible]	[illegible]	[illegible]	[illegible]
Within groups	[illegible]	[illegible]	[illegible]			
Total	[illegible]	[illegible]				

Table 4. Results of the ANOVA

This shows that there is significant difference in the infiltration rates recorded at the different dates for the different initial soil moisture content.

The variation among the recorded data was analysed and the LSD values are given in Table 5.

Comparison between	LSD value at 1% level of significance
21/4/'98 and 25/4/'98	23.9917
21/4/'98 and 29/4/'98	25.2833
21/4/'98 and 09/5/'98	51.9088**
21/4/'98 and 18/5/'98	4.0000
25/4/'98 and 29/4/'98	1.29167
25/4/'98 and 09/5/'98	27.9171**
25/4/'98 and 18/5/'98	-19.9917
29/4/'98 and 09/5/'98	26.6254
29/4/'98 and 18/5/'98	8.2845

Table 5. LSD values of the ANOVA.

This shows that there is significant variation at 1% level of significance the values recorded at 21/4/'98 when the soil moisture was 24.06 % and 09/5/'98 when the soil moisture was 19.20%; at 25/4/'98 when the soil moisture was 18.28% and 09/5/'98 when the soil moisture was 19.20; and at 29/4/'98 when the soil moisture was 23.27% and 09/5/'98 when the soil moisture was 19.20.

Conclusion

Generally from the infiltration measurements, their analysis and results one can conclude that the initial soil moisture content of the soil affects the infiltration rate of the soil at first and then comes to a constant value as is also noted in Landon (1991) and Kulute (1986). The results also showed that the soil is suitable for irrigation when considering only infiltration rates.

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The Use and Dissemination of Technological Information Contained in Patent Documents in Ethiopia

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Abstract

The success of a multi-faceted socio-economic development effort by and large depends on technological progress. The patent system, which provides exclusive right over inventions for a limited period of time, helps to stimulate technological development not only by providing the requisite protection but also by making available valuable technological information through patent documents.The grant of a monopoly right over an invention may be regarded as a trade off between the state and the inventor. The latter is granted a limited exclusive right in return for prompt disclosure of new inventions so that inventions are not kept secret and society benefits from the disclosure thereof.

It is a standard requirement of most patent laws that patent applications contain a description that disclose an invention in a manner sufficiently clear and complete for it to be understood and used by a person skilled in the art. The rational behind this requirement is to facilitate the use and dissemination of technological information. That is to enable other persons to exploit the invention upon the expiry of the patent right or under prescribed conditions during the currency of the patent without the consent of the patent holder or to freely use it for lawful purposes such as research and development activities. Every year more than a million patent documents are published worldwide, describing about 350,000 new solutions to technological problems. The large quantity of the information published together with additional features makes patent documents the most valuable source of technological information. The information contained in patent documents, amongst others, is more comprehensive, recent and applicable than those contained in other sources such as scientific journals and books.

The use of such information will, inter allia, help to:

a) solve technological problems there by avoiding duplication of effort and wastage of resources,

b) Reorient research activities, and

c) Facilitate the acquisition and transfer of foreign technology.

The role the patent system plays as a source of technological information is therefore one of the basic justification for the introduction and establishment of the patent system in Ethiopia. A preliminary study made by the Ethiopian Science and Technology Commission (ESTC) revealed the need for technological information to enhance local inventive activity as well as stimulate the acquisition of foreign technology there by alleviating the socio-economic problems of the country as well as building up the national technological capability. Cognizant of the need for technological information and the role the patent system plays in making available the requisite information, a concerted effort was made to establish an appropriate and suitable national patent system in Ethiopia.

The Patent law, which is the first of its kind in the history of Ethiopia, was enacted in 1995. The ESTC established a patent, technology transfer and development department (PTTD) to implement the law. This created a favorable environment to collect technological information contained in patent documents as well as to render a technological search and information service. There was no single patent document consisting of full technological information in Ethiopia prior to 1993. Thanks to the concerted effort made, after the adoption of the national S& T policy, the issuance of the 1994 proclamation that entrusted the commission to deal with patent matters and the enactment of the patent law, at present there are more than 12 million patent documents consisting of valuable information related to technological solutions in different sectors. Researchers form institutes of higher education and research, entrepreneurs from public and private enterprises as well as relevant government organs have so far used the information. Some of the users have succeeded in improving their products while others developed new products.

The achievement made in building up of a huge technological information within a short period of time as well as the few results obtained by using the information are encouraging However, a lot remains to be done. The use and dissemination of the information is very low, when looked at from the point of view of the available huge collection of technological information and the technological needs of the country. This could be attributed to a number of factors ranging from lack of awareness to absence of a mechanism for easy access to the technological information.

In this paper, attempt is made to highlight the:

a. importance of technological information contained in patent documents,

b. experience in Ethiopia regarding the hitherto use and dissemination of the available technological information,

c. problems encountered and steps taken, as well as

d. Planned future activities.

Introduction

The success of a socio economic development effort by and large depends on technological progress. There is a direct co-relation between socio-economic development and technological advancement.

Countries that are known as developed in terms of their level of socio-economic development are generally technologically advanced. The technologically backward countries are those that have a low level of socio-economic development and are known as developing and least developed countries.

The various socio-economic problems of Ethiopia are results or reflections of, amongst other things, its technological backwardness. The multi faceted development effort of Ethiopia, therefore, requires the need to spur technological progress. This in turn requires the existence of a conducive environment. One of such environments is the patent system.

The patent system, which mainly consists of the law and the implementing insituations has evolved before 500 years and developed from time to time as an instrument of promoting technological development and enhancing socio-economic progress. The system is believed to play a positive role in stimulating inventive and innovative activities, facilitating the speedy disclosure and spread of technological knowledge and encouraging the transfer of foreign technology.

The discussion in this paper is limited to the role the patent system plays as a source of technological information. The paper aims at giving a birds eye view on:

a) The role of patents as a source of valuable technological information,

b) The advantages and importance of technological information contained in patent documents,

c) The experience of Ethiopia with respect to the use and dissemination of technological information, and

d) Highlight the problems encountered, the steps taken and give indication on future planned activities.

In order to help appreciate the value of the information, copies of patent documents containing technological information related to dam construction and published at different times are attached to this paper.

Patent as a source of technological information

The patent system that provides exclusive right over inventions for a limited period of time helps to stimulate technological development by making available technological information through patent documents. The grant of a monopoly right over an invention may be regarded as a trade off between the state and the inventor. The latter is granted a limited exclusive right in return for prompt disclosure of new inventions so that inventions are not kept secret and society benefits from the disclosure thereof. It is a standard requirement of most patent laws, including that of Ethiopia, that the patent description discloses the invention in a manner sufficiently clear and complete for it to be carried out by a person skilled in the art. The rational behind this requirement is to facilitate the use and dissemination of technological information. That is to enable other persons to exploit the invention upon the expiry of the patent right or under prescribed conditions during the currency of the patent with out the consent of the patent holder or to use it for lawful purposes such as R&D activities.

The described technological information is made available through patent documents. A patent document includes " both patents and patent applications as well as other official documentation such as ' Inventors certificates' and 'utility models' "/WIPO, 1987:4/.

Comparison between patent documents and other sources of technological information

Technological information may be made available through scientific journals, books, patent documents etc.,. However, patent documents are considered more valuable source of technological information than other sources. There are a number of features which makes patent documents more valuable source of technological information when compared with other sources of technological information such as scientific books and journals.

According to WIPO the number of patent documents published in the world is approximately one million each year and it is estimated that patent documents published annually describe approximately 350,000 new solutions to technological problems. The large quantity of the information published together with additional features makes patent documents, the most valuable source of technological information.

The information contained in patent documents, amongst others, is characterized by the fact that it is:

1) Not divulged in any other form or made available earlier than other sources: -Studies revealed that about two- third of the information contained in patent documents has never been published in any other form. An investigation made by the United States Patent and Trade mark Office (USPTO) showed that as much as 70 % of the technology disclosed in US patent documents from 1967-1972 has not been disclosed in non patent literature / WIPO 1999: 8/. Furthermore, the remaining one-third is made available in other sources, long after the information is disclosed and published in a patent document. The following table consists of examples of the time gap between the time the information is made available through patent documents and other sources.

Type of technological information's	Year of publication	
	Patent document	Other forms
Punch cards	1889	1914
TV	1922	1928
Jet engine	1936	1946

Table-1 Examples of gaps in the time of publication of information

2) Complete and practical – The information is not confined to the new technological information but also the prior art and contains ways of putting it in practice. Patent laws often require that a patent application disclose the information in a compete and adequate manner to enable a person skilled in the art to put to use the technological information with out the assistance of the inventor. Furthermore, the applicant has to describe the best mode of using or applying the invention.

3) Easily accessible- the information is classified according to international patent classification. Patents dealing with the same technological problem have the same classification symbols and are grouped together. The international agreed numbers for the identification of data (INID code) also help to identify the information irrespective of language barrier. The same kind of information is indicated on all patents and independently of the difference in language. For instance (22) is for date of filing (30) for priority date.

4) Immense: - patent documents contain practically everything that represents the contribution to the knowledge of mankind in the field of technology back to the end of 19th century. Today there are more than 40 million published patent documents.

5) Not secret :- the information can be freely used for lawful purposes such as R and D as well as freely exploited in a country where it is not protected. Patent protection is territorial in its nature. So long as an invention is not protected in a country, it is deemed to fall into the public domain despite that it is protected elsewhere. As a result inventions that are not protected in a given country can freely be exploited.

6) Relates to a single technological information and contains comprehensive technical, commercial and legal information.

Advantages of the technological information contained in patent documents.

The technological information contained in patent documents has a number of advantages. The information will, interallia, help to:

a) Solve technological problems by avoiding duplication of effort and wastage of resources.

Development of technological solutions is a painstaking and costly activity. It often requires time, labor and effort of personnel, the availability of the necessary infrastructure such as laboratory facilities, information and documentation service that entail a huge investment and financial outlay. Such an investment will be wasted if made to develop what is already available. Re-inventing the wheel is a serious problem. Millions of dollars are being wasted due to lack of information on what is already available elsewhere. One study revealed that 30% of all R&D in Europe duplicates work already done which in monetary terms is over 100 million US dollars / Eduardo R. Fernandez, WIPO, 1997:9/.

b) Re- orient inventive and innovative or research and development activity. The bibliographic data together with the reference to the relevant prior art and the description of the invention in patent documents will enable researchers and competitors to be informed of current technological developments and findings in their field of activity and reorient their own activity.

c) Facilitate and overcome problems related to selection, negotiation, acquisition and transfer of foreign technologies

The information helps, interillia, in alleviating the problem developing countries such as Ethiopia face in the identification, selection, negotiation, acquisition and transfer of foreign technology due to lack of information on alternative sources of technology. Blakeney explained that a " patent document presents concrete solutions of technological problems in a standard, concise and easily accessible form. The comprehensive information contained in patent documents permits receivers of patented technology to see precisely what they will be receiving together with an evolution of comparable technology and alternative solutions" / Blakeney 1989:85/

d) Essential to government institutions such as Patent Offices and Investment Authorities to effectively discharge their functions and tasks. The information will help such offices, amongst others, to decide on patentbility of inventions and approve or disapprove technology transfer agreements.

Experience of Ethiopia

General

The collection, use and dissemination of valuable technological information, amongst others, presuppose the existence of a national patent system. Such a system was absent for a long period of time in Ethiopia.

A preliminary study made by the ESTC revealed the need for technological information to enhance local inventive activity as well as stimulate the acquisition of foreign technology there by alleviating the socio economic problems of the country as well as building up the national technological capacity. Cognizant of the need for technological information and the role the patent system plays in making available the requisite information, a concerted effort was made to establish an appropriate and suitable national patent system.

In 1995 the first patent law was enacted, entrusting the ESTC to administer the law. This was a millstone in the establishment of a national patent system. One of the basic justifications for the establishment of such a system in Ethiopia was the recognition the system plays as a source of valuable technological information.

The ESTC established the PTTD to administer the patent law and to serve as a data bank of useful technological information contained in patent documents and render information service.

Availability or collection of Patent documents

There was no single patent document consisting of full technological information in Ethiopia prior to 1991. Thanks to the concerted effort made after the adoption of the national Science and Technology policy in 1993, the issuance of the 1994 proclamation that reestablished and entrusted the commission to deal with patent matters, the enactment of the patent law in 1995 and the establishment of the PTTD, concerted effort was made to collect patent documents and related literature.

This effort bore fruit as a result of the assistances secured from WIPO, regional offices such as the European Patent Office (EPO), African Regional Industrial Property Organization (ARIPO), national offices such as the United States Patent and Trademark Office (USPTO), Japan Patent Office (JPO), and United Kingdom Patent Office (UKPO). To date more than 12 million patent documents contained in print and electronic from are available

1	CD-ROM	2617	1994 TO PRESENT	USPTO, WIPO, EPO, JPO, ETC	1 CD-ROM= 21 vol. of Encyclopedia Britannica
2	DVD-ROM	862	1790 TO PRESENT	USPTO	1 DVD-ROM= 7 to 10 CDs
3	MICROFILM	4660	1969 TO 1991	USPTO	
4	Paper form	93 volumes of British granted Patent applications	1884 until 1991	UKPTO, EPO, ARIPO etc.,	
5	Related Literatures	199 + 39 Periodical Titles			These include Patent world, European Intellectual Property Review, Industrial property journals and books

Table-2 Holdings of Patent Information Sources of PTTDD

1	USPAT	1116	1994 to Present	USPTO	CD has been changed to DVD
2	WORLD-ESPACE	695	1989 to 1998	WIPO-EPO	Full text
3	ESPACE-ACCESS	47	1969 to 1998	WIPO-EPO	Bibliographic only
4	GLOBAL-PAT	262	1971 to 1998	EPO	First page of an application
5	PAJ	583	1974 to Present	Japanese Patent Office	Abstract only
6	Espace-SI	4		Slovenian Patent Office	-
7	IPLEX	4		WIPO	National laws and International treaties
8	IP statistics	3		WIPO	Industrial property applications filed with and titles granted by member states IP offices
9	IP Class	2		WIPO	International patent classifications

Table.3 CD-ROM Collection

at the commission. Further more patent literature such as journals and books have been collected using the resources of the commission as well as through the mechanism of exchange of documentation established with foreign national and regional Industrial Property Offices. Details can be seen from the tables below:

As can be seen from above, compact discs (CDs) are the major source of the available technological information. The CDs are collected from different sources and are of different types. The number and types of the compact discs as well as their coverage is summarized under the flowing table

Use of patent documents

Researchers from institutes of higher learning and research, entrepreneurs, public and private enterprises, Banks as well as government bodies have used Patent documents.

The number of users has been increasing from time to time. At present on average about eight requests for technological information service are made daily. The frequent users of the service have made some of the requests.

Despite the increasing trend, the users are few and they come from limited regions. The period between September 2000 and April 2001 is taken as an example to shade light on the number and type of users as well as the regions from where they came.

The following two tables summarize the number and type of users as well as the regional distribution of users that accessed the technological information during the aforementioned period.

Types of users	Total number	Percentage	Remarks
1. Individuals	52	100%	
1.1 Professionals	36	69.24%	Diploma and above
1.2 non-professionals	13	25%	Certificates, students etc.,
1.3 unspecified	3	5.76%	Not stated in the application
2. Institutions	23	100%	
2.1 Public	12	52.5%	
2.2 Private	11	47.5%	

Table-4 users of technological information form October 2000 to April 2001

Almost the entire request except one is met using the sources available at the commission. One of the requests was met using the free state of the art search service made available by WIPO to developing countries.

The types of request range from requests for information of addresses of companies to the state of the art search in specified areas of technology. Requests for technological information are made by filling in a technological information service request form. The applicant, in his request, will indicate the type and area of technology for which he seeks information. The areas for which technological information is requested can be seen by taking the period between October 2000 and April 2001 as an example in the table below.

The specific areas for which information is sought for and made available to the users may further be elaborated by taking the human necessity sector as an example. The following table depicts the areas for which requests were made, the type of information and the number of pages of technological information supplied during the above-mentioned period.

The applicant often is given a list of relevant information consisting of bibliographic data on the subject. The full text is made available after the applicant identifies the relevant information. The information may be supplied in print or electronic form depending on the choice of the applicant. When the information is given in a paper form, the user is required to pay $0.25 cents for a page. When it is made available in an electronic form, the applicant is required to bring in a blank compact or floppy disk.

The search for and making of available of the technological information takes, depending on the type of request, minutes or days. In the latter case the average is two days.

Some of the users have reported that they have developed a product, which is as good as the imported one, while others have said that they have improved existing products or are in the process of developing new products.

The present use and the few reported achievements are encouraging. However, a lot remains to be done in promoting the importance and use of the technological information contained in patent documents.

Dissemination of technological

Users and regional areas	Total	Number of Applications Received	Percentage	Remarks if any
1. Indiv. Prof.	36			
1.1 Addis Ababa		33	91.1%	
1.2 Oromiya		2	5.3%	
1.3 Amhara		1	2.7%	
2. Non-professionals	13			
2.1 Addis Ababa		13	100%	No form other regions
3. Unspecified	3			Not mentioned in the request form
4. Private Institutes	42			
4.1 Addis Ababa		9		
4.2 Oromiya		3		
5. Public institutions	18			
5.1 Addis Ababa	7	63.64%		
5.2 Oromiya	2	18.18%		
5.3 Amhara	2	18.18%		

Table 5: - Regional Distribution of Users

information

Dissemination of the technological information contained in patent documents is made through selective information dissemination activities as well as general dissemination using print and electronic media.

Attempt was made to render a selected information dissemination service at the initiative of the commission. Selected bibliographic information consisting of titles of inventions and abstracts supported by the most appropriate drawings and deemed relevant to identified fields of activities were sent by the commission to 140 institutions requesting them to identify the information for which they need full text. The institutions include research organization and institutes of higher learning, public and private enterprises. Fifty percent of them responded and were sent full patent documents. Further more, bibliographic information related to inventions, patented by the USPTO since 1969, were supplied to the Ethiopian Agricultural Research Organization (EARO) and the Federal Micro and Small Scale Enterprises Development Agency (FEMSEDA), through compact discs, upon request. The quarterly patent Gazette, that was launched in June 2000 and is being published periodically, has also been used to disseminate selected technological information.

Efforts have also been made to create and strengthen awareness on the importance of the technological information contained in patent documents using workshops, print and electronic media etc.

Since 1993 the commission has organized on average two workshops or seminars either alone or incorporation with regional and international organization such as ARIPO, EPO, and WIPO. In addition, efforts were made to exploit opportunities offered by others and to synthesize potential users about the patent system in general and patent documents in particular. Papers were presented at fora organized by professional associations, Addis Ababa Chamber of Commerce and government bodies in Ethiopia

The print and electronic media have also been used to popularize patents and the role they play as a source of vital technological information. In this respect, interviews were given to and broadcasted by radio stations. Articles were written and published in national and local newspapers as well as journals.

In order to effectively promote the use and dissemination of technological information, potential institutions have been identified and requested to designate focal units and persons. Fifteen of these institutions positively responded. Focal person had been given an introductory course and practical training in information search and retrieval. Moreover, a committee comprising of five focal persons from five focal institutions was set up to promote the use and dissemination of technological information.

Type of information	Total no. Of pages	Full text (pages)	Bibliographic (pages)
A. Human necessities	2327	1925	402
B. Performing operations, transporting	452	385	67
C. Chemistry and metallurgy	2659	2337	327
D. Textile and paper	61	44	17
E. Fixed construction	182	151	31
F. Mechanical engineering, lightening, heating, weapons blasting	627	574	53
G. Physics	340	283	57
H. Electricity	383	352	31

Table-6-Information transactions by class from oct.2000 to April 2001

Problems encountered and steps taken

1. The collections of patent documents until very recently were limited to those published since 1969 and 1994 for bibliographic and full text of technological information respectively

Cognizant of the fact that the information embodied in earlier published patent documents are essential to meet the needs of the country, attempt was made to collect them. As a result it is now possible to collect and make available technological information published as early as 1790.

2. The importance and type of the technological information contained in patent documents as well as their availability is by and large unknown. Some of those who knew the availability of the information lack understanding of the type of the information. A good number of such users seek information on price and market of technology and request for a project feasibility study. In order to alleviate this problem, information users guide is prepared, print and electronic media as well as workshops and seminars have been used to sensitize potential users.

3. The information service is inaccessible to potential users. The patent documents are collected at the patent office in ESTC, Addis Ababa. One has thus need to come to the office. This

A 61 Agriculture, forestry, animal husbandry, hunting, trapping, fishing	441	412	29
A 22 Meat dairy, meat & vegetable processing, poultry or fish	68	-	68
A 23 Food or feed stuffs, their treatment not included in others	334	240	14
A 41 Bath wear	100	0	100
A 43 Footwear, footwear accessories	133	33	100
A 61 Medical and veterinary science hygiene	1253	4237	41

Table 7-The technological information used in the field of human necessities

may be one of the reasons for the low level of use of the information.

In order to overcome this problem, focal persons and units have been identified and information service has begun to be rendered in identified potential institutions. Currently, it is possible to fill in search request forms and receive the required information through focal points. Furthermore, two of the focal units, namely EARO and FEMSEDA are in a position to render a bibliographic information service.

4. There was no feed back mechanism. Information was continuously provided with out receiving a feed back on what was obtained using the same. Recently information is supplied together with a letter asking the users to inform back the returns obtained. As a result, now encouraging feed backs have been received.

5) In ability to correctly specify the technological information needed. Some of the users had a difficulty of clearly specifying the technological information they need. As a result, there were times when a bulk of information is supplied for the users to sort out the information they deemed relevant.

6) Lack of seriousness and commitment :- Very few users insisted that they badly needed a certain information. When the information is ready they failed to come and collect them. These had created bad feelings amongst the staff.

8) Shortage of manpower and lack of adequate skill could not help to refine the information service and build up an information system and database. To overcome this problem, a proposal was developed and a request submitted to the Federal Civil Service Commission for the establishment of a technological information and documentation unit. The proposal has now been accepted and additional four vacant posts have been created. A database consisting of the profile of users as well as depicting the information transaction is created. This database helped to learn about the status and trend of the use of technological information.

9) The information service has so far been rendered can be characterized as arbitrary. It is not rendered to meet defined objectives and attain set goals. There is no strategy and action program. The areas that should be given priority have not yet been identified. Information service is manly rendered when potential users make a request.

This is a serious problem and requires serious thinking. To this end, there is a plan to study the experience of other countries and develop a strategy and action program.

Future Plans

In order to strengthen and promote the use and dissemination of technological information contained in patent documents thereby ensuring that the system makes meaningful contribution to national technological capacity building as well as socio-economic development, the following activities have been planned.

1. To develop a strategy and action program in line with the national development strategy and program. In the strategy the areas of emphasis will be identified and prioritized, schemes will be identified to make the service measurable and out put oriented etc.

2. To shift from search of relevant information and provision of specific information to information processing and production of monographs and making available of synthesized information

3. To develop an information network to facilitate search and retrieval of information at focal units by potential users

4. To develop and build up the skill and experience of the staff and personnel at the focal units.

Conclusion

The use and dissemination of patent information, when compared to the available information and the expected need for the same, is very low.

The existing legal and institutional framework is conducive for the use and dissemination of technological information. The ongoing effort and the commitment of the government are encouraging.

The enactment of the patent law and the establishment of the implementing institution have already facilitated the collection, use and dissemination of patent information. The legal and institutional frame work for patents have not only increased the collection of patent documents as a result of foreign and local applications for patents as well as acquisition of foreign documents and publications but also facilitated the dissemination of patent information.

However, strategies and action programs should be worked out to enhance the wider use and dissemination of the huge collection of technological information. Moreover, there should be a scheme that would help to know the technological and socio-economic impact of the use of the information. The data that may be collected through such a scheme will help in further promoting the use of the technological information by potential users in the country.

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Lake Water Balance Model for Natural and Man Made Impact Assessment Under Limited Data Situation: The Case of Abaya and Chamo Lakes

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Abstract

The Abaya and Chamo Lakes are found in the Southern part of Ethiopian Rift Valley Lakes Basin. Little information is available regarding the water resources systems of these two Lakes. In this paper, methods used to generate necessary water resources data, modelling of the water balance and there by impact of water use, sediment transport and deposition are highlighted. In order to develop the water balance model, the watersheds of the lakes system are developed under GIS and the watershed characteristics are derived. The morphometry of the Lakes are investigated by undertaking bathymetry survey. The hydrological and hydro-meteorological component of the system have been also investigated by developing relevant database and information system and establishing regional relationships as well as rainfall-runoff model. These information systems have been integrated to model the water balance of the Lakes which simulates the water level. Using the simulation model various scenarios have been investigated. These include: natural water balance condition, water use under various exploitation levels and sediment input of various magnitudes. Based on the simulations result and computation of life expectancies, it is found that sediment inflow and deposition threaten the two Lakes. Keywords: **Bathymetry survey, capacity curves, GIS, life expectancy, MOWBAL rainfall-runoff model, sedimentation, water use, LAKEBAL water balance model.**

Introduction

In the Southern part of Rift Valley Region of Ethiopia there are two natural Lakes, namely Abaya and Chamo Lakes, and little information is available about these Lakes. The watershed of the Lakes is about 18,500km² including water area and currently inhabited by more than 3 million people with growth rate of about 3% per annum. These Lakes are important shallow Lakes and among others importance, to inhabit a number of aquatic animals and to modify the climate of the area. Yet there are evidences that they are heavily influenced by human activities and endangered Lakes unless proper precautionary measures are undertaken in the Lake's watersheds. In order to investigate the available water resources quantity in the lakes as well as impacts and influences of natural and man-induced factors a water balance model of the two Lakes have been developed.

The knowledge of water balance of lakes and reservoirs is an essential component of water management. Water management decision as far as possible should be based on a thorough quantitative understanding of the hydrologic cycle of the lakes/reservoirs in the basin. In developing country like Ethiopia, the quantitative understanding of individual components of the hydrological system themselves is difficult. This paper focuses on developing a water balance model, and describe shortly methods employed to obtain the physical characteristics of the watersheds and the lakes as well as the components of hydro-meteorological elements of the water balance components under limited data situation. The developed information is used for the simulation of lake water level. Furthermore, impacts of various influences such as sediment and water use are described and expected life of the Lakes under sediment load are discussed and measures to reverse the deteriorating situation are briefly discussed.

2. Model Equations and Soultion Procedure

Basic Equations

The input and output components of the water balance of a lake or reservoir depend not only on the physical dimension of the water body, but also on the climatic, hydrological and geological factors affecting the water body and its surrounding areas (Ferguson, H.L. & Znamensky, V.A., 1981,1984). The water balance equation can be written, from continuity equation at any time, which is governed by the conditions that the water volume remains constant. The continuity equation intern governed by conservation of matter, which described by equilibrium between added water volume or depth, lost water volume or depth and change in volume or depth as:

$$V_{in} - V_{out} + P - E - \Delta S = 0 \qquad (1)$$

Where V_{in} is surface and subsurface inflow; V_{out} is surface and subsurface outflow; P is precipitation volume; E is evaporation volume; S is change in storage.

Alternatively, parameters can also be similarly defined in terms of depth of water. In ideal situation variables of the water balance equation are computed separately, and providing closed result. In practice however, the compu-

tation leads to a discrepancy or residual error, . Considering the error term, the above equation can be rewritten as:

$$V_{in} - V_{out} + P - E - \Delta S \pm \delta = 0 \quad (2)$$

In the above equations parameters can be distributed as:

$$V_{in} = V_{si} + S_{ui} \quad (3)$$

$$V_{si} = \sum_{g=1}^{ngw} V_g + \sum_{f=1}^{nuw} V_{ug} \quad (4)$$

$$V_{out} = V_{so} + V_{uo} \quad (5)$$

Where respectively, V_{si} and V_{so} are sums of surface inflow and outflow; V_{ui} and V_{uo} are sub-surface inflow and outflow; V_g are V_{ug} are gauged and ungauged inflows; *ngw* and *nuw* are number of gauged and ungauged watersheds. The error term, , is treated component wise.

Solution Procedure

The water balance model equations written in the above form, using various water balance components can be used to compute and simulate the water volume, area, depth or alternatively unmeasured water balance components. The intention of the water balance in here is to simulate the water level and compute volume, area and their temporal variability on monthly or yearly time spans. In order to simulate the water level, volume based or depth-based equations, which have equal applicability, can be employed. The depth based simulation procedure has been employed for results in this paper and described by the following steps:

1. Compute initial parameters such as area and volume from the initial depth as boundary conditions,

2. Assume, mean area in time period i, $A_{mi} = A_{1,i}$, where $A_{1,i}$ initial lake area,

3. Compute change in depth, Z_e from

$$\Delta Z_i = \frac{(PF \cdot p - EF \cdot e) \cdot A_{ii} + V_{si} - V_{oi}}{A_{mi}} \quad (6)$$

A_{ii} is area of the lake for evaporation and rainfall computation, with p and e are rainfall and evaporation depths respectively. PF and EF are rainfall and evaporation correction factors, which are used to adjust rainfall and evaporation on the lakes.

Depth at the end of the simulation interval is:

$$Z_{2,i} = Z_{1,i} + \Delta Z_i \quad (7)$$

4. Compute $A_{2,i}$ the area at the end of time interval i from area elevation curve, compute $A_{m,i}$ from :

$$A_{m,i} = \frac{A_{1,i} + A_{2,i}}{2} \quad (8)$$

5.Repeat steps 3 & 4 until reasonable agreement in Z obtained,

6. Compute, volume $V_{2,i}$ at the end of time interval, i, using capacity curve,

7. For the next time interval $Z_{1,i+1}$, $A_{1,i+1}$, $V_{1,i+1}$ are described by $Z_{2,i}$ $A_{2,i}$ $V_{2,i}$

3. Input Data Process, Structure and Data Structure of Data Elements

The program for water balance named, LAKEBAL, has been developed and the modelling process constitutes three stages:

- Pre-processing of input data and selection of model parameters
- Simulation and computation of water balance components by executing the simulation program
- Post processing of output from simulation result

Figure 1 shows the sources of various components of the input data elements and their interaction in the modelling process.

Data of water Balance Components

The components of the water balance, such as runoff, rainfall and evaporation, lake morphometry and etc., were not existing and these components have been developed in the wider scope of a research associated to this paper, refer Seleshi and Horlacher (1999, 1, 2). The data can be stated as watershed data, lakes morphometric data, meteorological data, runoff data and peculiarities in hydrology of the watersheds. The composed data for hydro-meteorology totals 27 years of Abaya and 22 years of Chamo Lake on monthly basis. The watersheds of the two lakes drainage basin have been modelled combining ArcView GIS (developed by ESRI) and Watershed Modelling System (WMS) hydrological model (developed by Brigham Young University, USA). While the former has been employed for Digital Elevation Modelling (DEM) the latter has been used for Digital Terrain Modelling (DTM) in derivation of extensive hydrological parameters, such as slope, basin area, perimeter, etc. Figure 2 shows the derived main sub watersheds of the two Lakes Basin. After refining the sub watersheds capturing the locations of interest such as gauge stations and lake outlets, the entire basin was subdivided in to 52 sub-watersheds. The watershed data under the GIS environment masks the Lake mor-

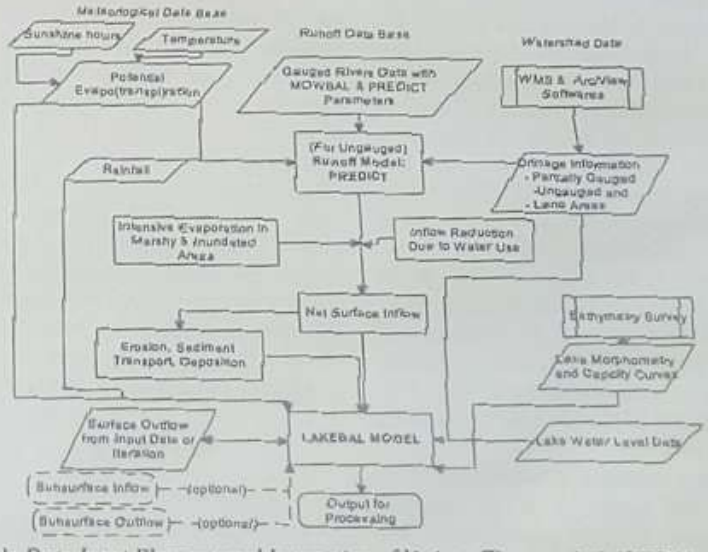

Fig.1: Data Input Elements and Interaction of Various Elements in LAKEBAL model

phometry due to data unavailability. In order to close this gap, a bathymetry surveys of the two Lakes have been undertaken combining Global Positioning System (GPS) and Echo-sounder. As a result the digital information system of the two Lakes water body, physical morphometric characteristics such as area, perimeter, length etc., as well as capacity curves have been developed. Figure 3 a) and b) provide a derived elevation contour map of the Lakes.

Figure 2: Watersheds of Abaya and Chamo Lakes

ance model and to generate runoff using rainfall-runoff model where inflow data are not available. In order to estimate the watershed and lake meteorological monthly data, a modified Thiessen polygon has been developed to estimate rainfall, temperature–elevation relation ship has been established to estimate temperature and thereby evapotranspiration estimation is made possible using Thornthwaite's procedure. Most of the area in the two Lakes basin is ungauged (only 43.9% of land area is gauged). While the data of gauged areas have been used, a rainfall-runoff model based on monthly water balance concept was developed, to estimate ungauged portion of the watersheds as well as the missing elements of data in the simulation period. The detail of this model is discussed in Seleshi (2000). Components of the subsurface flows are accounted via surface modelling and direct accounts are disregarded. Certain peculiar characteristics regarding the hydrology of the watersheds such as intensive evaporation due to wet land and inundation areas, hot springs, water uses in irrigation are accounted as these elements affect the magnitude of inflow components. Furthermore, surface outflows

unavailable. The existing Lake level records constitute three gauge stations on Abaya and one station on Chamo Lake. While the Abaya Lake data could be filtered, corrected and missing values are filled by comparing the stations, in the case of Chamo Lake data certain years of monthly uninterrupted records at the beginning and end of simulation periods could be used, because the intermediate values are associated with shift of stations and change of recording mechanisms.

4. Calibration of Parameters and Simulation Results

Calibration

The *EF* and *PF* parameters are used as calibration parameters. Optimum values of these parameters can be selected by minimising the error terms between measured and simulated Lake water level using ordinary least square procedures or by visual inspection of plotted results combined with regression equations. The optimum values of the calibration parameters can be set for various scenarios of investigating impacts on the lakes.

Simulation Result Using Lakebal

Due to uncertainty on the data of the water balance components on one hand and the need to obtain acceptable accuracy between the simulated and measured parameters on the other hand, the simulation and comparison of results were carried out for various scenarios. Some of the results are provided below, and they include simulation under no outflow and no sediment consideration, with outflow and no sediment deposition, with outflow and sediment deposition. In all cases the water use and water inflow reductions due to peculiarities in hydrology of the watersheds around the lake's periphery have been considered. In addition to the discussion given below, Figures 4 and 5 provide the simulation results.

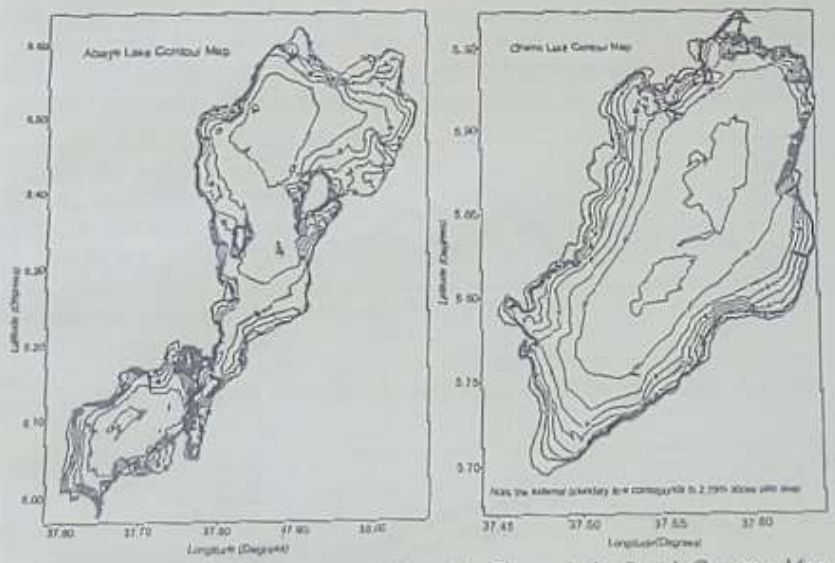

Fig.3 a) Abaya Lake Depth Contour Map b): Chamo Lake Depth Contour Map

Meteorological data such as rainfall and evaporation on the Lakes and the identified watersheds are important elements to compute the water balance are accounted in the simulation model from the gauged information or by trial and error where such information is

Initial Simulation without Considering Outflow

The first simulations have been made for both Lakes without considering outflows. After a number of trial simulation, it is shown in Figures 4

and 5 with respective description the simulation run of Abaya and Chamo for no outflow conditions, under the best selected parameters which suites simulation of level before commencement of outflows.

Simulation Considering Outflow

The simulation considering outflows are converged with *EF* parameters of 1.83 and 1.75 and *PF* parameters of 0.85 and 0.90 respectively for Abaya and Chamo Lakes. The higher evaporation factor for Abaya Lake is caused by higher heat absorption capacity of the Lake, underestimation of the method of evapotranspiration as well as uncertainty of the data derived from lake periphery. The lower rainfall factor is due to possible pluviometric depression effect of the rainfall falling on the Lakes. The coefficient of determination of the regression of measured and gauged values for Abaya and Chamo Lakes under these conditions are 0.87 and 0.99 respectively. Analysis of error shows, the simulation result is highly sensitive to local error, and as such if an error due to data occurs at a particular point, the error propagates in the subsequent simulation periods and shows apparent errors.

Simulation Considering Estimated Sediment

The effect of deposited sediment on the lake is clear and is detrimental to the water carrying capacity of the Lakes. The sediment delivered in to the Lakes has no outlets and fully deposited. Sediment load entering the Lakes particularly that of Abaya is high in magnitude. The causes of the large quantity of sediment are associated to intensified erosion in the catchment area due to deforestation, overgrazing and poor farming practice. In terms of Lake level simulation, the effect of inclusion of sediment deposition is to loose the bottom capacity of the Lakes and thereby an increased water level. In order to quantify the effects of sediment, unfortunately data of neither monitoring of sediment transported and delivered in to the Lakes nor adequate sediment measurement at some points in the rivers systems is available. In order to assess impact of sediment on the Lakes, 2 pairs of three various conditions of sediment inputs were evaluated. These are yield or concentration based under tolerable moderate and high sediment rates. These rates are based on watershed yield based to be 0.1, 2 and 25 t/ha per year respectively (scenarios I-1, I-2, I-3) and the concentration based to be 0.02, 4 and 25 kg/m³ respectively (scenarios II-1, II-2, II-3). Based on the various scenarios of sediment input the water level simulation and the life expectancy of the Lakes were evaluated. The results of the simulation under concentration based high sediment consideration (scenario II-3) for both Lakes are included in Figure 4 & 5. Under this case (i.e. worst scenario with sediment input of 25kg/m³), the existence to complete disappearance of Abaya Lake is estimated at 207 years and that of Chamo is estimated at 467 years. The latter would be dramatically reduced once Abaya is filled with sediment and the existence of Chamo would be then few decades after Abaya's disappearance. Investigation of research catchments located outside the watershed of the Lakes, see Dawit (1996), and other rivers in Ethiopia which have similar watersheds and climatic characteristics as well as evidences of the sediment load (short period sampled data) in the tributary rivers of the Lake show, the sediment input in the two Lakes is rated medium to high rate. As a result the two shallow Lakes are threatened by the large deposition of sediment.

5. Conclusion

As briefly presented in above the two lakes are investigated. After studying the hydrology, morphometric and watershed characteristics, a water balance model have been developed. Summing up, for example, for Abaya Lake rainfall contributes 27.2%, runoff contributes 72.8% of the added volume. During no outflow condition, contribution of losses due to evaporation on the lake is 97.63%, existing water use reduces only 0.17% and other peculiarities reduce 2.2% of the available water of the Lakes. Surface outflow occurred during the simulation period during the period of 1977 to 1981. The water balance simulation enables assessment of impact of water use as well as modification of input parameters. While existing water uses is insignificant, the impact of sediment input in to the lakes which directly caused by in appropriate use of resources such as forest and land in the watershed have threatened the existence of these two lakes. Added to the above problem there is a growing need to expand water utilisation such as in drinking water supply, irrigation projects, etc. The water resource in the study area is not abundant and well distributed in time and space. The resource is scarce and the Lakes are highly vulnerable to disappearance, if proper corrective measures couldn't be undertaken. On the other hand, there is

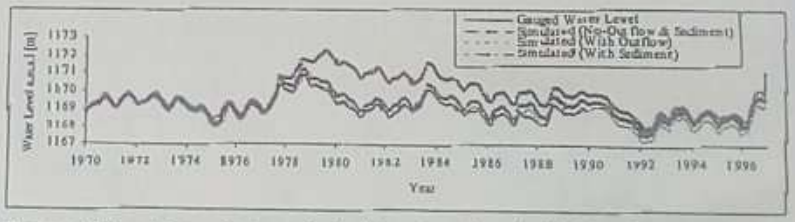

Figure 4: Simulation of Abaya Lake Water Level under Various Scenarios

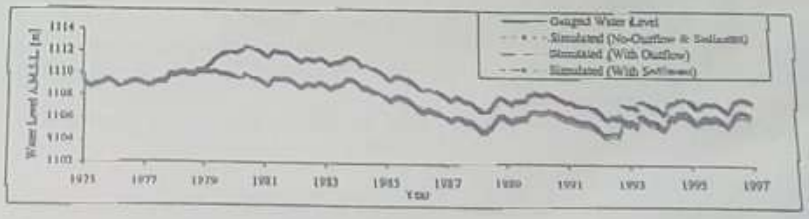

Figure 5: Simulation of Chamo Lake Water Level under Various Scenarios

a pressing need to utilise the land and water resources potential of the basins due to growing population. If the available water resource in the system is properly managed, it could be effectively utilised for regional development and preservation of the entire natural environment. The following are suggested measures how to reverse the existing detrimental situation and yet utilise the water resources more effectively.

- Program of erosion control measures in the entire watershed system: Forestation, terracing, prevention of overgrazing, avoidance of poor farming practices such as up and down tiling of land.

- Use of renewable and sustainable energy sources: development and use of hydropower, geothermal, bio-energy and sun energy instead of wood as a source of energy for cooking and heating, and there by reduce deforestation of the watershed, erosion and sediment transport.

- Replacement of wood construction material with other sources.

- Development of water and sediment control structures by choosing elevated reservoir sites there by on one hand sediment are forced to settle in the reservoir or before the reservoir by providing check dams, and on the other hand the stored water is exposed to lower evaporation.The evaporation difference could be employed in to consumptive and non consumptive uses as well as defined releases to flow through the rivers and streams to sustain the aquatic life in the rivers and wetlands leading to the Lakes.

- Increase of agricultural productivity through small to large irrigation schemes and thereby enable food self-sufficiency of the region and reduce deforestation for need of more agricultural land and accelerated erosion. In irrigation development, existing practice of water misuse and poor management should be corrected through proper training of the users.

- Environmental education on the importance of resource, implication of misuse of resources on ecology.

Acknowledgement

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Planning & Managment & Analysis of Sustainable Water Resources Project

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Abstract

This paper presents some aspects of planning and management aimed towards evolving a water resources project which can be defined as sustainable. As a part of analysis an objective function has been formulated considering various aspects, which can be broadly classified as the essential requirement for sustainability. This has been reduced to a simple case which is easily solvable by linear programming.

Introduction

Most of the so called third world countries are striving to provide a better standard of living for their population. With ever growing population in these countries, their quest for better growth requires large scale development, that may lead to a progressive transformation of economy and standard of living. Under the new dispensions such transformations must be defined interms of sustainability. The Ethiopian water Resources management policy aims to develop suitable and reliable water resource management strategy. Coupled with. Sustainability development was first proposed by Brundtland commission (1987). As per the commission," sustainable development should ensure that it meets the needs of the present with out compromising the ability of future generation to meet their own needs".

The concept of sustainable development needs translation into action and programmes. The Brundtland commission did not give any advice on what should be done to make sustainable development a reality.

The meaning of sustainability to some extent was clarified by Bruce (1992). He defined it in terms of environmental, economic and social sustainability, which can be briefly stated as under:

1. Development must not damage or destroy the basic life support system of our planet earth, the air, the water and the soil, and the biological systems.

2. The development must be economically sustainable to provide a continuous flow of goods & services derived from Earth's natural resources, and

3. The development requires sustainable social systems at International, national, local & family levels to ensure the continuity of services produced, and of sustained life support systems.

Further attempts to clarify thinking has been made in this direction at UN conference on Environment and Development in Rio De Janerio, Brazil in June 1992.These ideas related to water resources development project has been crystallized by the committee on water Resources Research(COWAR) of the International council of scientific unions (ICSU) through a comprehensive report (Jordaan etal 1993). Erich J.plate (1993) delivered a key note address at the XXV IAHR Biennial Congress at Tokyo. These ideas are summarised as under:

Sustainability & water Resources development Projects

Water Resources development aims at using the water resources of a region to meet the needs of the people, agriculture and industry and to protect people from the hazards of floods and droughts and pollutants.

Sustainable water resources development can be considered to be an integrated activity involving engineering, economic & environmental and qualitative issues as well as resource policies. Water resources projects will be sustainable if water of sufficient quantity & quality is available at an acceptable price to meet demands and quality standards of the population of the region now and in the future without causing the environment to deteriorate. Water resources development projects must be properly planned and managed to meet the above noted objectives. The planning and management issues are briefly discussed in the following paragraph.

Planning sustainable water resources developments projects.

Following points can be envisaged as the requirements for planning of sustainable water resources development projects (SWRDPs). Understandably all these points may not be applicable to a given situation. However, care must be given to these, where ever applicable.

1. Consider the project as an integral part of societal system, and take into account all interactions of the project into society & environment.

2. Consider non-structural solutions as a first alternative, which may require inter- disciplinary and inter sectorial investigations.

Catchment area management techniques and other non structural measures are being given greater emphasis these days as a measure of flood control project compared to making elaborate and costly flood control structures.

3. Give due consideration to alleviate water quality problems during operation caused by the system, which implies that negative impacts of water quality are avoided or taken care of as part of plan.

4. The project should interfer as little as possible with the natural environment, that means that planning of SWRDPs should include a full assessment of beneficial and adverse environmental impacts, and of means to alleviatiate adverse effects.

5. Include as a part of planning an assessment of risks, and precautionary measures for preventing disasters. Risk assessment comprises possible failure states of the structures as well as possible failure states of the system (such as not being able to meet demand during drought.)

6. Give due regard to uncertainties of both supply & demand, which implies that careful hydrological studies of water supplies and careful evaluation of water demands of population and industrial growth be made giving due regards to margins of errors and stochastic variability.

7. Include consideration of social impacts caused by dislocation of people, or stress during system failure which includes alleviation measures for flood and drought.

Rehabilitation of displaced persons from the area of submergence due to reservoirs created on the upstream side of a new dam has been a neglected issue in many countries although hydro-community is not to be blamed for it as the organization involved in R&R process are those from civil service attached to government. However it must be given adequate care in future planning & construction as it has already earned enough of bad name for Hydro-communities.

8. Include provisions to cope up with changes which may be caused either by changes in demand, by changes in land use or by changes in climate whereas, it is recognized that climate changes usually develop more slowly, and leave more time for adjustment, land use changes caused by forest clearance or urbanization may be fast leaving very little time for correction & adjustment.

9. Involve the people that are affected by the project in the planning process, so that projects become optimally adopted to living conditions and to local environments which implies carrying out social work to prepare the people for changed situations once the project is completed as compared with the existing situations, so that they will be prepared to support the complete project.

10. As far as possible eliminate potentials for future international conflicts- which means that the effect of project in the upper part of river basin should be planned so that they are not detrimental to down stream residents of river basin, in particular in large international basins.

Management of Sustainable water Resources development project

Engineering and planning alone with not provide a sustainable system. The best development project will not be sustainable unless a suitable management structure exists for operation and maintenance of the system.

An endeavor should be made to:-

(i) Make available competent staff of managers, technicians & workers for operation & maintenance of project, this creates the necessity for developing an appropriate infrastructure for a system if possible before construction & operation of the project begins.

(ii) Ensure that a continuous supply of water is available at all times for all needs-which implies that the system is operated according to the carefully developed rules, including the rules to be applied during shortages and excesses.

(iii) Continuously improve the performance of the system to achieve maximum efficiency-which requires that the operation rules are readjusted from time to time to meet changing needs and to over come planning deficits.

(iv) Make management cost conscious. Consider and promote means of covering the cost of operation and maintenance in an equitable and efficient way which means that financial revenues are generated and management decisions are made to make the system function as it was intended at.

(v) Continuously monitor the performance of the system which implies setting up an appropriate data gathering and analyzing system to determine the conditions of the system and proper functioning of its elements at regular intervals.

In Ethiopia there is an utter paucity of data. Various consultants carrying out feasibility or pre feasibility studies of projects are some how crafting the data, which may on may not be appropriate. As such the sustainability of the project may become questionable.

Framework envisaged by Ethiopian Water Resources Management Policy

Ethiopian Water Resources Management Policy (MOWR Ref 8) provides a strategic framework for integrating environmental planning into new existing policies, programmes & projects. It recognizes the importance of incorporating environmental factors in to development activities from the onset. The main aims of the policy which are in direct correspondence with sustainability are given as under:

I) To ensure that the ecological processes and life support system are sustained, biological diversity is preserved and natural resources used in such a way that their regenerative and productive capabilities are maintained indefinitely.

II) To incorporate full economic, social and environment costs and benefits of natural resources development into planning and accounting processes, by comprehensive valuation of the environment and services it provides.

III) To improve the environmental of human settlements so as to satisfy the physical, social, economic, cultural and other needs of their inhabitants on a sustainable basis.

Tools for analysis of sustainable Water Resources Development Project

Four main categories tools foreseen to be more actively used (S.P. simonorich-1997)are:

- Systems analysis (simulation, optimization & multi objective analysis)
- Information systems (spatial and temporal data processing, data base management tools and GIS)
- Artificial Intelligence (expert systems, neural net-works, objects oriented programming, fauzzy analysis etc)
- Technological (computer graphics, animation etc). All the tools to be used in sustainable water resources project analysis should be incorporated into the decision support framework.

Optimization & analysis for sustainable development of WRD Projects

On the basis of above discussions, the following issues for any WRD proposed project can be envisaged for sus-

tainable development:

1. Maximise benefits from proposed project
2. Minimise the cost of the proposed project
3. Maximise the beneficial environmental effects of the project
4. Minimise adverse environmental effects
5. Maximise the beneficial effects of the project on the society.
6. Minimise the adverse effects that a society may have to bear like
   relief and rehabilitation of people
7. Maximize and optimise the use of local resources, men material & know how.

An objective function for 'n' number of projects each having 'j' number of uses can be formulated on the basis of Denove programming approach (Kuniyoshi Takeuchi-1998)

The objective function along with constraints is written as

$$\text{Max } f = \sum_{i=1}^{n}\sum_{j=1}^{m}(a_{ij}Q_{ij} + e_{ij}Q_{ij} - b_{ij}Q_{ij} - b_{ij}X_{ij}) - C_{ij}Q_{ij} \quad \ldots\ldots(1)$$

$$\text{Constraints} \quad \sum_{i=1}^{n}\sum_{j=1}^{m} I_{ij}Q_{ij} \le I$$

$$\text{Subject to} \quad Q_{ij} \le \overline{Q_{ij}} X_{ij} \le \overline{X_{ij}}$$

Non-negativity constraints

$$I_{ij} \ge 0$$
$$Q_{ij} \ge 0$$
$$X_{ij} \ge 0$$

Here, a_{ij}= Annual benefits per unit component of i^{th} water resources use in the j^{th} project

Q_{ij} = Quantity of water resources of the i^{th} use and j^{th} project

b_{ij} =Net annual benefit expected from most economic use of additional resources needed for the i^{th} use of water resources in the j^{th} project.

X_{ij} =other decision variables with respect to additional resource use for the i^{th} use of water in j^{th} project

C_{ij}=Annual cost per unit component of the i^{th} water use in the j^{th} project.,

e_{ij} = Annual net benefit by considering return expected from favourable impact of project on the environment and adverse impact of the project on the environment due to i^{th} water resources use in the j^{th}project

S_{ij}= Annual net benefit by considering the return expected from favorable aspects of project on society such as better health, opening up new jobs, new communication, new trades, new recreational facilities etc and adverse aspects caused by displacement of people, loss of trade etc due to i^{th} water resource use in the j^{th} project.

I_{ij}=Investment per unit component of the i^{th} water resources in to j^{th} project.

I= Total investment available.

$\overline{Q_{ij}}$ = Maximum quantity of water available for the i^{th} water resources use of j^{th} project.

$\overline{X_{ij}}$ = maximum limit imposed on the use of a given additional resource for the i^{th} project.

The above formulation can be solved by the known techniques for the solution of linear programming problems.

Proper quantifation of the environmental issues and social issues etc listed from point 3 to point 7 are quite difficult as such it is may be difficult to select proper decision variable and to maximize or minimise them.

For environmental effect it will be appropriate to prepare an EIA , so also a proforma for social impact analysis should be prepared for each project. In case the negative impacts are substantial and are making beneficial effects meaning-less the project should be rejected.

In some simple cases equation 1 proposed can be further elaborated. One such case is propagating the conjunctive use of surface and ground water for irrigation purposes. This will reduce any adverse environmental impacts of irrigation projects interms of water logging, to save the land from becoming saline, addition of gypsum and additional water required for leaching has also been considered as in eq. (2). This may lead to optimum policy of water application and optimum cropping pattern.

The linear programming formulation of the problem (Singh 2000) to maximize annual net return subject to the constraints on the availability of water and other resources are given as under:

$$\text{Max } f = \sum_{i=1}^{n}\sum_{k=1}^{4} a^{x}_{ijk} W_{ijk} - \sum_{j=1}^{2} C_j S_j - \sum_{j=1}^{2} \overline{C_j}(1+L_r)T_j - \sum_{j=1}^{2} G_j(1+L_r)T_j \quad \ldots\ldots(2)$$

Here, i=crop, i=1,.....,n,

j=growing season, j=1 for winter season and 2 for summer season

k=Level of irrigation 1 to 4

a^{x}_{ijk}=net return per hectare excluding cost of irrigation and gypsum from crop i grown in season j with level of irrigation k.

a^{x}_{ijk} = area allocated in hectars to crop i grown in season j, with level of irrigation k

C_j=cost of applying one ha-mm of surface water in season j

S_j=Surface water allocated in ha-mm of tube well water in season j.

T_j= Tube well water allocated in ha-mm in season j excluding requirements

G_j= Cost of applying gypsum per ha-mm of tube well water

L_r= Leaching water requirement in fraction.

Subject to

1) Water requirement constraints

$$\sum_{i=1}^{n}\sum_{k=1}^{4} a^{x}_{ijk} W_{ijk} - S_j - T_j(1+L_r) = 0 \qquad \forall j$$

Here W_{ijk}=water required in ha-mm by crop I, grown in season j with level of irrigation k.

i)Land area constraint

$$\sum_{i=1}^{n}\sum_{k=1}^{4} a^{x}_{ijk} \le A_j \quad \forall_j$$

Here, a_i=land area occupying coefficient for crop activity i is equal to 1, if crop is grown in season j, otherwise it is zero and A_j=Total land avaible in season j.

ii) Water availability constraints

(a) Surface water

$$S_j \le AS_j \qquad \forall_j$$

(b) Tube well water

$$(1+L_r)T_j \le AT_j \qquad \forall_j$$

Here, AS_j= surface water available in ha-mm in season j after allowing for losses and AT_j=Tube well water available is ha-mm in season j, after allowing for losses

iii) Maximum allowable area

$X_{ij} \le A_{ij}$ Here , A_{ij} Maximum allowable area in ha available for allocation to crop i in season j

$\overline{A}_{ij}$=min" area in ha which should be allocated to cop is season j.

Here, $\overline{A}_{ij}$ =Minimum area in ha, which should be allocated to crop i in season j.

An attempt for sovling a similar formulation by Linear programming was made by khepar (1980)

Spread sheet- Based WRM computational Models

A Microcomputer programme for sustainable planning of water Resources development Projects in Ethiopia has been prepared as spread sheet based WRM computational models by Ababe Belachew and Bogale G/mariam (2000). The computational framework analysis include AWTI BCI, AWTIAGR, AWTIPWS, AWTIRRS, AWTIYLD and AWTI START, The programme is quite useful in planning sustainable WRD projects in Ethiopia.

Conclusion

Sustainable planning of water resources projects needs recapitulation of all aspects of the project. Particularly important amongst these are the environmental and social aspects. The sustainability of the project should not be defined only in terms of beneficial and attractive returns but in what way the resources are optimally utilized, and saved, environment preserved or upgraded for future generation. Formulation of objective function with given constraints and solving the same by process of optimization may be a good tool for sustainable analysis.

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Interaction Between Ecological Parameters and Methodological Alternative for Ecological Nomenclature

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Abstract

This study assessed ecological status and association between forest endowment and rainfall amount in Karnataka state, India. The search for possible association between rainfall and forest endowment was done by taking average of seventy years annual rainfall and forest cover proportion (FCP) of 19 districts in the state. Though the result on ecological interaction between rainfall and forest cover proportion had been found to be paradoxical, it was useful in enhancing the debate on the same issue. In the process of assessing the existence of association between rainfall and forest cover proportion, the study introduces methodological alternative of naming ecological status of districts. In effect, new type of nomenclature is reached.

Introduction

Ecological interaction is one of the areas of interest in this study. It is a proven fact that forestry develops hydrology. It is equally interesting to ask whether rainfall develops forestry. For this purpose, the presence of association between rainfall and forest cover proportion was assessed at district level. The assessment based the rainfall and forest cover data of the districts in the Karnataka State, India.

Karnataka State, one of India's southern states, has a forest area of 3.68 million ha (GOK, 1995). This covers 20 per cent of the geographical area of the State. However, official reports from satellite imagery show that the forest cover does not match with this number being only 3,234,300 ha. (1993).

In light of this, this study tests the existence of ecological interaction between rainfall and forest cover proportion. Apriori hypothesis to this study is that proportion of forest cover and rainfall amount in a state have significant association.

Methodology

Kolmogorov-Smirnov Two Independent Samples Test

Average of seventy years of annual rainfall of each district in the State was taken. This average rainfall data was for the duration from 1923 to 1993. In addition to this, the forest cover proportion of each district was calculated for the year 1997 (as Forest Cover/ Geographical Area). Both district-wise rainfall and forest cover proportion values are given in Table 1.

After checking goodness-of-fit with normal distribution using Kolmogorov-Smirnov one sample test, respective mean and standard deviations were calculated for these two district-wise cross sectional data. Thus, district-wise mean rainfall and forest cover proportion and their associated standard deviations were obtained.

Depending on values of mean and standard deviation, the rainfall (RF) data was categorized into ranges by taking one, two and three standard deviations about the mean of rainfall. The categories were named as Low RF, Moderate FR, High FR and Very High RF ranges.

Likewise, the forest cover proportion (FCP) values were categorized into ranges by taking one, two and three standard deviations about the mean of FCP. The categories were

District	70 years Rainfall average (Mm) (1923-1993)	Forest Cover (Ha) (1997)	Geographical Area (Ha) (1997)	Forest Cover proportion (Percent)
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]			[illegible]
[illegible]	[illegible]			[illegible]

Table 1 District-wise 70 years average rainfall & proportion forest cover

		RAINFALL				
		LOW	MODERATE	HIGH	VERY HIGH	TOTAL
	LOW	10	1	0	0	11
FOREST	MODERATE	1	0	0	1	2
COVER	HIGH	0	2	0	0	2
PROPORTION	VERY HIGH	0	0	3	0	3
	TOTAL	11	3	3	1	19

Table 2: Contingency for Rainfall and FCP: Observed Frequency

named as Low FCP, Moderate FCP, high FCP and Very High FCP ranges.

Based on these categories of rainfall and forest cover proportion ranges, the number of districts that fall under each category were counted and arranged into a four-by-four contingency table. This is shown in Table 2. Afterwards, Kolmogorov-Smirnov two independent samples test was applied on this contingency table.

This test statistic is used to assess the presence of significant association between rainfall and forest cover proportion in the districts. In other words, the presence of ecological interaction/ association between rainfall and forest cover is analyzed. To apply Kolmogorov-Smirnov two independent samples test, cumulative and relative cumulative frequency distribution for each sample observations is determined using same intervals of both distributions. For each interval, one step function from the other is subtracted. The test focuses on the largest of these observed deviations. Let $S_m(X)$ be the observed relative cumulative

frequency distribution for one sample of size m, $S_n(X)$ be the observed relative cumulative frequency distribution for the other sample of size n.

The Kolmogorov-Smirnov two independent samples test statistic is given by $D_{m,n} = Max |S_m(X) - S_n(X)|$ for two-tailed test. For decision, the observed value of $mXnXD_{m,n}$ is calculated and compared with critical value (Siegel *et al.* 1988).

The null and alternative hypotheses to be tested by the Kolmogorov-Smirnov two independent samples test are

Null Hypothesis H_0: There is no association between rainfall and forest cover proportion.

Alternative Hypothesis H_1: There is association between rainfall and forest cover proportion.

Result

The districts in Karnataka receive different amount of rainfall and have varying forest cover proportions. Rainfall (RF) data ranges from a minimum of 569 mm in Bijapur to a maximum of 4029 mm in Dakshina Kannada. Likewise, forest cover proportion (FCP) ranges from no forest cover in Raichur to maximum of 81.5 per cent in Kodagu. The data is given in Table 1. The ground reality shows that Kodagu district had the maximum forest cover proportion, 81.5 per cent. On the contrary, the least of this figure was in Raichur with no forest cover.

Both rainfall (RF) and forest cover proportion (FCP) data were tested separately for their goodness-of-fit to normal distribution before looking at spread of their values around their corresponding means. This was done using Kolmogorov-Smirnov one sample test. Rainfall data was found to follow normal distribution with mean of 1230 mm and standard deviation of 968 mm at one percent level of significance. The value of the test statistic was 1.47. Likewise, FCP was found to follow normal distribution with mean of 20 per cent and standard deviation of 26 per cent at five per cent level of significance. The value of test statistic was 1.34.

These mean and standard deviations were used to classify the districts by taking the spread of standard deviation (SD) about the respective mean of each rainfall and FCP value. This means the ranges were spread as mean-1SD, mean+1SD, mean+2SD and mean+3SD for both rainfall (RF) and FCP values. Each range was given a category name as low, moderate, high and very high RF or FCP. Finally, four ranges and four categories for RF and FCP were found.

Accordingly, the categories for RF spread from 288 mm to 1230 mm to 2172 mm to 3114 mm to 4056 mm. The ranges and categories are presented in tabular form in Table 3. These four categories are named as Low RF, Moderate RF, High RF and very High RF districts.

Rainfall Range (mm)	Category
288 to 1230 (mean - 1 standard deviation)	Low Rainfall District (LRD)
[illegible] (mean + 1 standard deviation)	Moderate Rainfall District (MRD)
[illegible] (mean + 2 standard deviation)	High Rainfall District (HRD)
[illegible] (mean + 3 standard deviation)	Very High Rainfall District (VHRD)

Table 3. Rainfall range & category

Similarly, ranges and categories were made for FCP. The categories spread from 0% to 20.3% to 41.5% to 70.7% to 95.9%. The ranges and categories are presented in tabular form in Table 4. Like rainfall categories, names are given for FCP categories as Low FCP, Moderate FCP, High FCP and Very High FCP districts.

The result of this ranging and categorization based upon rainfall and forest cover proportion values helped to categorize different districts in the State. The result is presented in Table 5. This categorization provides rather better understanding of each district in terms of the ecological parameters; rainfall and forest cover proportion. Compared to ordinary data on these respective parameters, this in fact is a relative categorization of districts with new type of nomenclature. This nomenclature has ordinal scale of measurement like Low, Moderate, High and Very High RF and/or FCP districts.

Looking at the categories under FCP, two districts Uttara Kanada and Kodagu emerge as Very High FCP districts, three as High FCP districts (Chikmaglur, Dakshina Kannada and Shimoga), one Moderate FCP district (Mysore) and remaining emerge as Low FCP districts. This shows that 13 out of 19 districts i.e. 68.4 per cent of the districts are low FCP districts in Karnataka.

Similarly, 13 out of 19 districts are again Low RF districts in the State. The number of districts in each category is given in a four-by-four contingency table(see in table 2).

FCP Range (Percent)	Category
[illegible] (mean - 1 standard deviation)	Low Forest Cover Proportion District (LFCPD)
[illegible] (mean + 1 standard deviation)	Moderate Forest Cover Proportion District (MFCPD)
[illegible] (mean + 2 standard deviation)	High Forest Cover Proportion District (HFCPD)
[illegible] (mean + 3 standard deviation)	Very High Forest Cover Proportion District (VHFCPD)

Table 4. Forest cover proportion &category

An attempt was also made to see whether the number of districts falling into a particular cell (observed frequency) correspond to expected number of districts (expected frequency) in the contingency table. In few cases the observed frequency is higher than the expected frequency for districts with Low RF-Low FCP, Low RF-Moderate FCP, Moderate RF-High FCP, High RF-Very High FCP, and Very High RF-High FCP. It is also observed that there are no representations for many of the cells in the contingency table, for example, Low RF-High FCP cell. However, highest number of districts were concentrated in Low RF-Low FCP cell of the contingency table.

Kolmogorov-Smirnov two-independent samples test statistic for the contingency table is 18.99 at 10 per cent level of significance. The corresponding hypothetical value is 171. As the calculated value is less than the critical value, the null hypothesis is accepted. The result is given in Table 6. The result means that there is no asso-

District	Forest Cover Proportion (Percent)	Category	[illegible] Rainfall Average (Mm) ([illegible])	Category
[illegible]	[illegible]	LFCPD	[illegible]	LRD
[illegible]	[illegible]	LFCPD	[illegible]	LRD
[illegible]	[illegible]	LFCPD	[illegible]	LRD
[illegible]	[illegible]	LFCPD	[illegible]	LRD
[illegible]	[illegible]	LFCPD	[illegible]	LRD
Chikmaglur	[illegible]	HFCPD	[illegible]	MRD
Chitradurga	[illegible]	LFCPD	[illegible]	LRD
Dharwad	[illegible]	LFCPD	[illegible]	LRD
Gulbarga	[illegible]	LFCPD	[illegible]	LRD
Hassan	[illegible]	LFCPD	[illegible]	MRD
Dakshina K.	[illegible]	HFCPD	[illegible]	VHRD
Uttara K.	[illegible]	VHFCPD	[illegible]	HRD
Kodagu	[illegible]	VHFCPD	[illegible]	HRD
Kolar	[illegible]	LFCPD	[illegible]	LRD
Mandya	[illegible]	LFCPD	[illegible]	LRD
Mysore	[illegible]	MFCPD	[illegible]	LRD
Raichur	0	LFCPD	[illegible]	LRD
Shimoga	[illegible]	HFCPD	[illegible]	MRD
Tumkur	[illegible]	LFCPD	[illegible]	LRD

Legend:
LRD = Low Rainfall District; MRD = Moderate Rainfall district; HRD = High Rainfall District; VHRD = Very High Rainfall District
LFCPD = Low Forest Cover Proportion District; MFCPD = Moderate Forest Cover Proportion District; HFCPD = High Forest Cover Proportion District; VHFCPD = Very High forest Cover proportion District

Table 5. District-Wise Category of Rainfall and Forest Cover Proportion

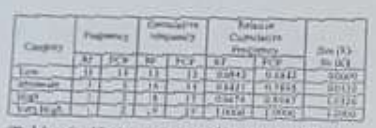

Table 6: Kolmogorov-Smirnov Two Independent Samples Test Statistic Procedures and its Result

ciation between rainfall and forest cover proportion at district level. Therefore, FCP is independent of rainfall amount. In other words, rainfall category in which a district exists is independent of its corresponding forest cover category. For example, district with low forest cover proportion does not mean that the district has also low rainfall amount.

Sample sizes of Rainfall and Forest Cover Proportion are 19 each respectively. They are denoted by m and n. Thus, the maximum difference, $D_{m,n}$ is 0.0526.

The test statistic:

$mXnXD_{m,n}$ = 19X19X0.0526 = 18.99

Critical value for m = 19 and n = 19 at 5 per cent level of significance is 181. As observed value of 18.99 is less than the critical value of 171, the null hypothesis that *there is no association between rainfall and forest cover proportion at district level* is accepted.

Discussion

The ranges on rainfall and forest cover proportion were obtained using their respective mean and standard deviations (SD) as mean - 1SD, mean + 1SD, mean + 2SD, and mean + 3SD. These ranges were found after both data had been found out to have significant goodness-of-fit with normal distribution using kolmogorov-Smirnov one Sample test. This gives conceptual strength to the procedure followed so far. The categories were named as low, moderate, high and very rainfall and FCP districts. The categorization on RF and FCP values was finally arranged in a four-by-four contingency table.

The result of Kolmogorov-Smirnov two-independent samples test showed that there was no significant association between rainfall and forest cover proportion in the districts. In other words, there was no enough evidence to conclude that there was significant ecological association between rainfall and forest cover proportion at district level.

This result is contrary to apriori assumption that there is significant association between rainfall amount and forest cover proportion in the districts. The reason lies on the absence of adequate natural forest in the State. Another reason is the aggregation of data at district level. Both rainfall amount and FCP values at village levels could give a better result. Additional factor is the aggregation in amount of rainfall data. Seventy years average annual rainfall data for each district is taken for the study. Season wise amount of rainfall, rather than annual, could be good indicator.

It was found out that twelve out of nineteen districts concentrated in both low rainfall and low FCP category (Table 2). This was because majority of the districts had RF and FCP below the mean of 1230 mm and 20.3 per cent respectively. These 12 districts amount to 63 per cent of the districts in the State. This gives total area of 13,243,500 ha which amounts to 68 per cent of the geographical area in the State.

Conclusion

The whole scenario of this study does not provide strong evidence for the association between rainfall amount and forest cover proportion. However, new nomenclature has been introduced to explain the ecological status using ordinal scale of measurement as low, moderate, high and very high rainfall and forest cover proportion districts. Accordingly, 63 per cent of the districts (12 out of 19) have both low rainfall and low forest cover proportion i.e. below average in Karnataka State. This amounts to 68 per cent of the geographical area in the State.

Thus, one can conclude that district-wise rainfall data does not help in explaining the microenvironment. Such type of data are misleading and highly contradicting the assumption of strong association between rainfall and forest cover proportion unless this type of assumption is restricted to microenvironment, not to district level.

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Some Aspects of Watershed Management - A Case Study of Hare River, South Rift Valley of Ethiopia

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Abstract

Hare watershed was described, the problems and their causes investigated and strategies to manage the watershed were also forwarded. The data were collected from field survey, group discussion and secondary sources. Hare watershed is situated in Lake Abaya-Chamo basin, south rift valley of Ethiopia, with altitude ranges from 1200 to 3480m above the sea level. The Hare river, originating from the southwestern high lands, flows in the NW-SE direction for about 52km. and empties to Lake Abaya. Its maximum width is about 10km and covers about an area of 25000 ha land. The respective annual mean rainfall of the upper and lower watershed is 7,81.9 mm and 1392 mm, with respective bimodal and monomodal pattern.The total population of the watershed is 72554 with the household land holding of 2 ha to 0.5 ha. The dominant land use is cultivation which constitutes about 60% and forest about 4% of the total land. The soils of the watershed include Fluvisols, Alisols, Leptosols, Acrisols and Cambisols. The major problems in the watershed include among others, soil degradation, deterioration of drainage, water logging and poor agricultural water management. Biophysical environment, lands cover and land management and –socio economic aspect cause these problems. The latter includes population growth, wide spread poverty, and insecure land tenure system, which are common for the entire watershed. The other problems vary from place to place in the watershed in such a fashion that the upper watershed is highly affected by leaching and decline in soil water depth while in the lower watershed the major problems are drainage deterioration. Thus different management measures should be taken depending on the problems which occurred in the land capability class. Accordingly in the upper watershed crop management, land management and structural works to be applied. While in the lower watershed the proposed management practices are with the objective of improving the drainge conditions of the area. The other most important point to be addressed for the whole watershed is the socio economic aspect.

Key words or Phrases: south Rift valley-Ethiopia; watershed management; Hare watershed problems; Soil degradation; soil-water conservation

Background And Significance

Watershed is defined as an area drained by a stream in such away that all flow originating in that area is discharged through a single outlet (Sureh, 1997). Watershed deterioration is caused by incorrect use of lands and poor management practices. The subsequent impacts of the problems of the watershed include decline in biomass production, low agricultural production, and the down site effects such as silitaion of reservoirs, lake, and channel, decline water quality and quantity. Ultimately it results is lose of production potential of land which leads to indispensable famine the death.

The floor of the rift valley is a low-lying land that in most cases material which are eroded from the high lands are deposited and hence erosion problem is not a serious one. However flooding, water logging and silitation problems seriously affect the area.on the other hand the escarpment is suffering of erosion because of the steep topography and incorrect land management which is exacerbated by high population pressure. Equally important problem in the area is pollution of water sources, which is mainly due to the industrial establishments.

With assistance from the World Food Program, the Ethiopian government mounted a "food for work" project, provide each worker with 3 kg of grain and 120g of vegetable oil for each day work. In the first 12 months of 1980 alone, more than 34 million working days were completed. By the end of the year 1982 nearly 150000ha of agricultural land had been terraced, 70 000ha of land reforested, 30000 fruit trees planted and 4200km of roads and 400 irrigation ponds constructed. Hence probably the largest scale of physical reclamation of eroded land in Africa took place (FAO, 1990).

However, large-scale afforestation is also unpopular with local people because it reduces the area available for livestock grazing while forest protection implies denying access for fuel wood collection. A balance between the competing requirements of conservation and production is clearly needed if popular support for soil conservation work is to continue without inducement such as Food-for-Work Program.

A land use plan to conserve steeper slope by restoring vegetative cover through closure by controlled grazing has been found to be more acceptable to the local people than large scale afforestaiom in isolation.

Thus adopting watershed management approach is therefore, crucial in achieving maximum protection and enhances the resource of the watershed. It includes the treatment of land by agronomic management and structural measures, which also be economically feasible and socially accept-

able in implement of the plan.

Interms of resource development, it starts from the most important one, that is, water and then extends to the resources of fuel, fodder, livestock and all associate components.

Different measures are adopted and executed carefully in each of the top sequences according to its capability (Narayana et al, 1990).

Thus in order to raise the agricultural productivity of the watershed, to protect, conserve and improve the natural vegetation, intensification of agriculture, to minimize soil erosion and to reduce the effect of sedimentation and other different purposes, identification of the extent and type of watershed problems and solutions accordingly are very indispensable.

The present study is therefore, designed to address the deterioration of natural resources of the watershed, and causes of the problems. Furthermore to suggest strategies to manage watershed and there by to increase agricultural production, increase forest product and flood control and sedimentation in the watershed.

Methods And Procedures Of The Study

Semi structured in depth interview combined with observation and repeated iteration were employed to secure information such as problems of agricultural production, livestock and wood resources, causes of low yield, indigenous knowledge of soil management, knowledge of soil erosion, causes of soil erosion, cropping calendar, available area for production, land tenure, land fragmentation, settlement pattern, population density, population number, agricultural practice, livestock management etc. and other different information which has come from the in-depth interview and observation. The interviewees comprised of the cross section of society, including farmer leaders, woman farmers, poor farmers, rich farmers, innovative farmers and extension agents

Group interviews (6-10 people) was also held with community to gather information such as land holdings, past land use history, and local history. Group interview can be self-correcting since participants often correct each other's information. It was also in detail discussed on specific topic who have intimate knowledge about the topic under consideration.

Moreover, information was collected by transect walks, by observing, listening, looking,

Identifying different zones and seeking problems and possible solutions.

Moreover, The different types of soil degradation determined namely, physical, biological and chemical degradation based on laboratory analysis. Moreover, secondary sources of data mainly from the office of the Agriculture of the wereda were employed.

Description Of The Watershed

Location:

The project site "Hare watershed" is situated under Lake Abaya Chamo basin of south Rift Valley of Ethiopia. It is located about 483 km south of Addis Ababa and about 7 km NNW of Arbamich and is crossed by Addis Ababa -Arbaminch asphalt road. The catchments roughly lies between 602'-6'1 8 'N and 3 7'27 -3 7'3 8'E (Fig 1).

The watershed includes parts of Arbaminch Zuria wereda (40%) and Chencha wereda (60%) of Gamu Gofa Zone, South Nation Nationality and People State. The catchment embodies about 18 peasant associations, which is the local level organization of farmers. The area of the catchment is about 25 000 ha.

Hydrology

Like wise any river in the Rift Valley, Hare river is originated in the south western highlands of Ethiopia, near Lanta area and flows in NW-SE direction, and ends in the lake Abaya. The Hare river catchment is bounded in the north by Sura ridge (a divide to Damee River), in the east by Zede ridge (a divide to Basso River), in the west by Woze ridge (a divide to Kulfo River)and in the south by Lake Abaya . The river Hare NW-SE extent is 52km. The catchment maximum width is about 10 km, covering an area of 25,000 ha.

The two most important tributaries of the Hare River, which found in the left bank, are Harare and Gina. However in general, there are many intermittent streams that join the Hare River. The pattern of the flow of the river is dendritic type as shown on the drainage pattern.

The respective highest average maximum discharge and minimum discharge is 8.25 and 1.62, which occurs in May. While the total monthly average is 9.34 million m3/s

Maximum river flow occurs between Aprils to May. The 2nd peak flow to the river occurs from September to October in response to climate. Hare River is the source of water supply for the upper catchment and it is also used for irrigation for the lower catchment.

Geomorphology and Geology

The geology and geomorphology of rift valley is assumed by the process occurred from Miocene to Pleistocene and the lower part of Hare River is no exception. While the upper part of the watershed as a part of the western high lands, is the result of the volcanic activities that took place in the territory period. In general the pattern of topography of the catchment is composed of flat plain (in the east- around Lake Abaya), hills (rift valley escarpment) and mountains (in the west - the upper catchment). Moreover, a fault occurs along the eastern boundary of hills (King and Brachall, 1975).

Slopes ranging from flat to steep slopes characterize the catchment. Of which, the sloppy topography comprises the largest proportion and found in the upper catchment.

The western and central part of the catchment that is the upper watershed is covered by the Ashangi group, which consists predominately of alkaline with interbed basalt pyroclasts and rare rhyolites. While the rocks of lower catchment are colluvium on foot slope, alluvium along river and lacustrine along lake which are derived from the above rocks (Geological map of Ethiopia, 1975).

Climate

The attitude of the catchment ranges from 1200 to 3480m above the sea level.

Based on altitude, the catchment exhibits kola (warm temperate) to

Dega (very cool) climate.

The average rainfall of the catchment, based on meteorological records of Arbaminch (1200m.a.s.l.) and Chencha (2700 m.a.sl) ranges from 781.9mm to 1392mm. Based on the records, two patterns of rainfall can be discerned, bimodal in low land and monomodal in highland.

In bimodal, the main rain occurs during the period of March to June and the peak is 148 mm in April. During this period the weather becomes more unsettled, and convergence of south easterly winds originating from the Indian ocean with a weakening north easterly air stream causes heavy rainfall to this area While the small rainy season (the 2nd peak) is in between August and November and the peak in October and amounts 92 mm.

On the otherhand, the rainfall distribution in highlands, is monomodal, which occurs from April to October, the high amount occurs in April, which amounts 185.4-mm. This is due to when moist wind from the Atlantic and Indian Oceans converge over the highlands.

The rain fall in the lowland is marked by short heavy bursts with the intensity of 100mm per hour where as on the high lands most intensity may only reach 60-70 mm per hour (King and Brachall 1975).

Frost is commonly (frequently) occurs in the upper watershed, because of the high altitude. It is common during April and June and the other occurrence period is in between October and November.

The maximum monthly mean temperature in upper catchment is 14.7 and the minimum temperature is 12.6 which occurs in February and September/ October months respectively. The mean average temperature in the lower catchment ranges from 22°c to 24°c, of which the mean maximum temperature (26°c) is in March and the lowest temperature from December to February.The temporal variation of temperature could be explained to the apparent movement of the sun. In the highlands the range is in between 13°c to 15°c. The areal variation is mainly due to altitude difference. The period of the maximum is the time of rainy seasons and sowing crops. Inconsequence, the weather is different from the other place.

Land use and Land Cover

Based on the criteria of classification of land use/land cover by FAO, the main land use/ land cover units distinguished in the watershed are forestland (least disturbed, highly disturbed), woodland, bush land, shrub land, cultivated land, swampy ~(wetland), bare land (degraded land) and others with respective proportion of 4%, 2%, 5%, 4%, 7%, 60% and 10%.

Soils

Eutric Fluvisols, Eutric Cambisols, Leptosls, Acrisols and Alisols are the major soil units identified in the watershed. Vertisols occur on alluvium deposition and stratified deposition of the toe slope. Cambisols develop on strongly sloping area of the lower watershed. Leptosols are formed over the residuals of the basalt of the upper slopes. They are characterized by shallow soil depth, below 30 cm. The Ah/ AB horizon of Acrisols and Alisols are overlying the cambic B-horizon. The CEC of Acrisols is below 29 cmol/ kg , which is lower than the CEC of Alisols indicating the high clay activity of the Alisols.

As a result of the parent materials, the soils of the lower watershed in general are characterized by high nutrient status and retention capacities. The pH of soils is also favorable for crop cultivation. However, low organic matter and total nitrogen limit crop cultivation in the area. And drainage problems. The shallow depth and the high erosion rate in Leptosols and Cambisols are another constraint of cultivation of the escarpment. Moreover Leptosols of the upper watershed is marked by high acid. In the upper catchment the pH is very low that the nutrient status of the Acrisols and Alisols are determinant of cultivation.

Livestock

The total number of livestock in the watersheds is about 29400-63400. The most important livestock in the area is cattle (34%) and sheep (34%). Goats, horse and mules are also raised in the area.

(Source: Survey of Agricultural Office)

Grazing land in lower catchment is found along the shores in steep slope (escarpments) in addition to some in pockets of land in the upper catchment. This land is the communal property. The main source of feed to cattle is this communal grazing land. The small children are responsible to look after cattle. Women also cut and carry grass for the cattle The grazing land is decreases from time to time with the expense of cultivation land. On the other hand the number of livestock is increasing which causes overgrazing.

Socio-Economic Aspects

The total population of Hare watershed is 72,554. Of which 68% dwells in upper and

Middle catchment while the remaining 38% lives in the lower catchment. The average density of population is 323 person/kM . The main ethnic groups are Gamo, Dorze and Ochollo. Their language is Gamugna, which is spoken by 95% of the population. Other languages are Ocholigna and Amharic.(Survey of Agricultural Office)

In the low lands there are about 1641 house holds with the average number of 8 members in each family where as in the high lands the house hold is estimated about 8025 with the average number of 8-15 in each family.

The variation in population density of the catchment is attributed to climate (mainly rainfall) and diseases (malaria). In the upper catchment the high population density is due to by high rainfall and there is no disease such as malaria. However the people from the upper watershed were used to cultivate the lower part by passing the nighttime in their home. This is mainly due to the low productivity of the upper catchment and the high population pressure. Latter on the people established permanent settlement in the lower watershed for example the people who lived in KollaShara of the lower watershed are migrants of the DegaShara of the upper catchment. Further more the collectivism and villagization during the Derg period also contributed to population settlement of the area, at which people were forced to settle.

In general therefore most people of the lower watershed were migrated from different parts mainly from the upper watershed. As mentioned they were moved down wards in searching of wood and cultivable land.

Before the 1974 revolution, the landlords owned the land. After the revolution the landlords system was abolished and land reform took place. The land, which was confiscated, from the landlords was distributed to farmers. Peasant Associations are responsible for administration, distribution and re-distributions of the land whenever necessary. Grazing and woodlands are commonly owned. Currently land is fragmented and the shortage of land is worsening mainly by high population growth .

The major source of income is agriculture production of crops and raising of cattle. The people also involve in off-farm activities such as weaving, trading and handcrafts.In the catchment there are 12 elementary school but about 78% of the population is illiterate (Agricultural Office of weredas).

The Hare watershed is not well managed and large area of cropland, grass and –forestland are seriously degraded. Under below is the problems related to cultivation, grazing land and forest resources and drainage problems discussed.

Problems Related to Cultivation

Different types of soil degradation cause deficiency of nutrients, decline in water holding capacity, problems of rooting anchorage, tillage difficulties, and drainage problems and flooding. These in turn result in the decline of agriculture productivity of the soil, increase in the susceptibility to crop failures and ultimately poor production, ending in famine.

In the upper watershed most soils are marked by shallow depth Much Lands of marginal area (steep slope, summit) are brought under cultivation. In addition, the soil is seriously affected by low available nutrients viz. N, P, K, Ca_{α} and Na. More importantly, the soil is suffered by high acidity, in most soils the p ranges from 5.0 to 4.7 which the characteristics of very strongly acid.

Nitrogen is essential for plant growth as it is a constituent of all proteins and nucleic acids and hence of all protoplasm. Nitrogen availability in upper watershed is at high level while in the lower watershed the level is very low. Hence the shortage supply of nitrogen limits the growth of plants by affecting the growth of leaf and the subsequent photosynthesis. Ultimately the yield declines. On the other hand by applying nitrogen fertilizer it is possible to get large yield.

Potassium is one of the essential element in the nutrition of the plant, and one of the three that are commonly in sufficiently short supply in the soil to limit crop yield; hence it often needs to be added regularly in the fertilizer. In the upper watershed potassium is at low level which imply that together with the small supply of nitrogen, the plants are stunted, their leaves are small and rather ashey-grey in color, dying prematurely, first at the tips and then along the outer edges, and the fruit and seed is small in quantity, size and weighty. Potassium acts as a corrective to the harmful effects of nitrogen and often required for crops receiving high level of nitrogen manure.

Calcium appears to be essential for the growth of merSistems and particularly for the proper growth and functioning of root tips, And to neutralize the undesirable effects of an unbalanced distribution in the soil. Ca deficiency in the upper watershed and it appears to have two effects on the plants nutrients it causes a stunting of the root system and it gives a fairly characteristics appearance to the leaf.

Water influences the various growth activity of plants in various stage of development such as seed germination, seedling emergence, photosynthesis, respiration, leaf size, and seedling (D.Pimental 1993). Stated another way the shortage of soil water adversely affects the above activities.

In the upper catchment of study area organic matter is high in cultivated land as well and but the problem is in lower catchment which is characterized by low organic matter.

Organic matter is another most important component affected by erosion. Organic matter has positive effect on water retention, soil structure a cation exchange capacity.

- Source of soil nutrients (95% of N, 15-80% of P)
- Formation of soil aggregates of desirable size porosity & stability which are critical to good soil structure and tillage.
- Positive affect an nutrient availability (since good structure promotes availability)
- Interrelated with soil –biota that maintains soil quality.

Therefore, when organic matter lost by erosion has an adverse impact on crop productivity & soil quality as well. It is studied that (D.Pimental 1993) by reducing of organic matter from 3.8 to 1.8%, the yield of corn reduced by about 25%. On the other hand irrespective of the amount of inorganic N fertilizer, the applications of annual manure show significant increment of yield.

The reduction of the depth of soil affects the capacity of soil to hold water & nutrients. Moreover, the problem of rooting anchorage and restricting rooting depth. In addition it creates problems of tillage.

In general, therefore, the reduction of crop productivity due to the low soil productivity is the result of the cumulative effects including water, nutrients, organic matter, and soil biota and soil depth. Thus, sometimes it is impossible to offset topsoil loss using fertilizer (D. Pie mental). This is primarily due to soil water condition which make nutrients less available and thus decrease the efficiency of nutrient utilization by plants. Therefore the cost of erosion include costs of extra fertilizer and irrigation. The ultimate impact is in lowering production. In the upper watershed mainly crop production is below the national average.

Problems Related to Wood Resources

The problem of erosion starts with the removal of natural vegetation by man for cropping grazing, fiel, etc. Deforestation is very high in the area, which has resulted in the decline of forest from 7.6% in 1966/67 to 5.2% in 1974 and at present it is by much below this rate. The high rate of deforestation accentuated erosion by affecting

the infiltration and run off. As Hurni estimates, the cropland, which is less than 15% of the total area of the county, accounts for 45% of the total soil loss while the rate of soil erosion in forest areas is negligible(1988).

The economic advantages the people get from the forest are reversed. At present the trees are found along the river valleys. The use of dung for burning has also lead to a decline in the structures and fertility of soil.

The main cause of deforestation is clearing of land for cultivation due to the increase population size and the low yield per unit area. The other factors of deforestation in the area include the people often cut wood and sell to the towns. The fisher man use wood from this forest to construct boat, moreover, the grazing land (swamp land-which is dry during dry season) is located adjacent to the forest and there by the forest land is thus accessible to deforestation and also people graze inside forest which ultimately resulted in overgrazing and the effect on forest land.

Moreover, in the watershed there is hardly planting of trees but people cut trees for various purposes. Furthermore, due to the heavy rainfall of 1997/98 by Elino effect and siltation, the lake water flooded considerable proportion of forest, and as a result trees in those area are drying up.

Problems related to Grazing Land

Animal health and nutrition are interrelated. Insufficient nutrition weakness livestock which inturn suppresses immunity. Malnutrition directly causes diseases.

The grazing land is in competition with cultivation land because of the shortage land for cultivation. People extend cultivation to grazing land (for example earlier there was grazing land around homesteads, but now changed to cultivation).

The other problem of grazing land is grazing land deterioration, which is due to overgrazing of cattle from the surrounding town. The poor ways of grazing and less affection on production of fodder are also causes for deterioration. More over the fodder shortage is also caused by increasing livestock per household, and high population. Which is due to increment of population as caused by immigration (mainly from upper watershed to lower watershed) and high growth rate of local people. Last but not least the other constraint is shortage of rainfall

The extent of the low fodder quality is explained to feeding in steep slope during wet season and on the other hand during dry season the condition is worth. In general therefore, high degradation of grazing land particularly of the water point, low quality of fodder and the cut grass is costly. The subsequent effect is in the decline of the quality of cattle, the prevailing of cattle diseases. And ultimately the livestock production is affected highly.

Furthermore, the availability of manure decline and thus the reduction of the organic matter of the soil. The degradation is also severe on steep slope where forest cover/bush land is found. This is due to overgrazing of the steep slope.

Others Deteriorating Problems of the Watershed

The off-site environmental effect of soil degradation problems are silitation, flooding and

water logging that are common to the lower watershed.

Water logging

Water logging is a serious problem in the lower watershed . Large area, about, 97ha of land are occasionally and permanently found under water. In a consequence it is a burning problem of these days because this is detrimental on the area available for cultivation All water logged area is found in the lower watershed, namely in KoltaShara PA 65 ha 2) ChanoChelba PA, 20 ha, 3) ChanoMile PA, 12ha . (Report of the Agricultural Office).

The texture of the topsoil; excessive water from dam irrigation site; absence of drainage line construction and the high seepage of the canal cause water logging.

Water logging causes anaerobic conditions and dentrification. And the subsequent impacts are the decline in yield and ultimately the land will be changed to waste land. In occasionally occurring area the effects are weed growing, difficult to plough and also increases the ~Na content due to capillary action because of high temperature.

Sedimentation

Sedimentation is a process of deposition of sediment by water. Sediment may be settled as any fragmented material, which is transported or deposited by water, air, or ice as natural agents. Among all, water is the most widespread agent of sediment transport. The sources of sediments are agricultural land, forest and wastelands, gully by concentrated run-off. The causes are the occurrence of flood in the watershed. The factors that affect sedimentation are land use and soil type 2 (catchment size 3) climate and rain fall.

The lower part of the watershed is highly affected by silitation, which is derived from eroded materials from the upper catchment. This is clearly indicated by the silitation of the weir dam of Hare-which was lasted for two years. Furthermore, the secondary canals are also filled by silt frequently and as a result clearing of canal consume large labor.

The siltation causes the dam (weir) malfunction. After its construction of 2 year silts filled it. The problem is also extended to the sub canal and on the farmers' field. Every year these canals are filled by silitation. Silitation also affect the water quality of the river, so as the Hare river.

Finally, since the soil is removed every year from upper watershed, in the lower catchment now deposited by soils, which are not as fertile, In this way the production will decline in the future.

Flooding

Flooding is an excess overflow or inundation from a river or other surface water bodies Flooding is another adverse phenomena that occur in the lower watershed. Once in a year during rain period large areas will be under water.

Flooding occurs in the lower catchment. Study shows that the peak flood occurs 4 times with in 7 year. However, flooding occurs every year. By flooding except Chano Dorga peasant association, the remaining lower areas

are badly affected. Moreover, the level of lake has risen and flooded the near by area every rainy time. As a result, forests, which are found along the shore, are dying as a result of water logging. This rising of lake is mainly due to siltation and the change of climate.

Water management problem

The irrigation water in the Hare catchment is used by traditional technique. This traditional way of watering plants has so many drawbacks. To mention farmers water their land until the allowed time to water ends irrespective of season. This is mainly due to the lack the crop water requirement.

Determinants Of Problems Of The Hare Watershed

The major problems that threat the natural resource and agricultural productivity of the Hare watershed is soil degradation and the decline in biodiversity. The extent of soil degradation problem in Hare watershed is very serious as evidenced by the different forms of degradation viz. siltation of the dams, large size of gully, shallow soil (exposed rocks), low productivity of soil are very few among others. However, the distribution of the types and extent of soil degradation varies from place to place in the watershed depending on topography, rainfall pattern, soil characteristic, and land use/land cover and management.

1. Causes of Soil Degradation

A clear understanding of erosion causes is a requisite to any planning aimed to protect the viability of erosion problem on agricultural enterprises" (S.A. El- Sawify) that is for the assessment of soil control.

Biophysical, land cover and land and socio economic conditions cause soil erosion.

(i) Biophysicalfactor

Biophysical factors embrace rainfall intensity, soil erodibility and slope.

A. Rainfall Erosivity

The intensity of rainfall in the lower watershed is very high. Where as in the upper watershed the long period and continuous flow of water, resulted in leaching, as shown by depletion of nutrients.

B. Soil Erodibility

The low organic matter in the lower watershed attributed to the detachment of soils. Moreover the soil type in the escarpment is sandy soil, which is relatively erodible. The soil erodibility in the Rift Valley is high mainly because of weak structure, lack of cohesion and low bulk density of the volcanic material commonly occurring in the Rift Valley.

C. Slope.

Slope gradient is another cause of erosion particularly, particularly the steep slope of the escarpment and the upper catchment. The removal of the large amount of soil in the escarpment is mainly the result of steep gadding which is also exacerbated by deforestation. The same is true in upper and lower watershed area the slope is steep. Moreover, the lower watershed is influenced by high rate of overland flow from adjacent uplands.

2.1 Land Cover and land Management

The main causes of soil degradation in the country in general and in the watershed in particular is the socio economic factors. The effective soil erosion abation can not be effective in the absence of the consideration of socioeconomic conditions. However it is neither quantifiable nor well understood. The followings are the frequent mentioned factors of socioeconomic conditions in the Hare watershed that mainly cause soil degradation.

A.Deforestation and Devegetation

The problem of erosion starts with the removal of natural vegetation by man for cropping, grazing, fuel, etc. Deforestation is very high in the catchment, which has resulted in the decline of forest from 12.3% in 1967 to 4% in 2000, that is the decline by about 77% (Engdawork Assefa, 20000). The high rate of deforestation accentuated erosion by affecting the infiltration and run off. As Hurni estimates, the cropland, which is less than 15 % of the total area of the country, accounts for 45 % of the total soil loss while the soil loss in forest areas is negligible (1988). Rate of erosion is less in areas where there is a good vegetation cover, such as in the areas of high potential perennial crops.

B. Over cultivation and overgrazing.

This is caused by high population size in the catchment. As a consequence, people cultivate the land without interruption throughout a year in order to survive. Moreover, the small size land of a family is distributed to their children, particularly for sons as they become adult and get marry since the law permits the inheritance. The subsequent effect of it is the land to be fragmented. Fragmentation is also promoted by polygamy marriage. Moreover in the lower part of the catchment people have been migrated to lower catchment in order to get more land and ultimately the land of the area is fragmented.

The size of livestock is increasing in the area and the concentration is high mainly in the watering site. Particularly in the lower part the watershed, the large number of cattle of the Arbaminch town graze in this common grazing land.

C.Misuse and mismanagement of lands.

The misuse and mismanagement of lands are resulted from ignorance, knowledge and the subsistence economy. It is manifested in the watershed by :

Cultivation of steep slope :- in upper watershed all mountains are cultivated. Although the people have been constructed terraces, it is old and collapsed. As a result a high surface run-off which comes from the adjacent steep slope.

The time of ploughing and preparation of seedbed and the commencement of rainfall is coinciding. Since the soil is uncovered, ultimately erosion rate very high.

Another destructive farming activity in the upper watershed is harvesting system, which is characterized by uprooting the harvest, and collect to home by doing this activity the soil is removed.

The extent and coverage of traditional conservation measure is very limited.

In the lower watershed people do not put dung on their farmland, which

is mainly due to ignorance. On the other hand, in upper watershed people used to collect residues for fuel/ burning from the remained uprooted plants. These activities therefore, adversely affect the organic matter of the soil.

Mountain part (the escarpment) is burned every year when the season is dry with the intention of to get grows good grass.

Lack of systematic land resource inventory and land capability classification and thus usage on land is improper.

There is lack of land security, which is detrimental factor for investing in the soil water conservation measures.

The extension program doesn't include the soil water conservation as a package. But the usage of fertilizer as a part of the package is an important aspect for conservation.

There is lack of appropriate tested technology to implement. In addition there was no activity with regard to soil water conservation measure, which have been carried out by government organization and non government origination despite of the seriousness of the problem.

Lack of awareness in recognition on causes, extent and consequences of erosion problems by farmers.

On government part, there is lack of incentives for who are practicing conservation measures.

2.3 Socio economic factor

One of the major factor that cause land degradation and the subsequent decline of agricultural productivity is socioeconomic factor which include among others land

The question of land ownership and occupation are mainly interrelated with the influences of the government on land use. These influences are manifested in land policy (by land allocation and distribution), supportive policies (such as, the policy of subsidies) and the role of government as landowner. The question of who has owned the land has exerted strong influences on the present land use pattern.

The tenure structure and the subsequent social structure that came into picture at different times exerted strong influence on the trends and pattern of distribution and management of land.

Though the Ethiopia highlands were deforested long time ago due to the long practiced agricultural system, force land instability occurred since the last one and half century. Among the different factors, such as population growth, the increasing demand for agricultural production, the rising demand for fuel wood, construction materials etc. The land use system was one of the major factors of deforestation. The system allows the community to graze on one's far in field after the crop has been harvested and removed. As a result, a farmer cannot practice any conservation works on his field. The supportive policy in fertilizer subsides of the peasant is very low. These ultimately result in decline in production, and as a result people forced to cultivate marginal areas by clearing forests and natural vegetation.

In Ethiopia since 1974, government the distribution of land to tenants was held in 1974 owns land. Then redistribution of land was also conducted The present government also followed the same policy on land

As a result of which land use pattern is influenced. Since the psychological impact on self feeling is declined among the people. Subsequently little attention to plant trees and to maintain forest. Moreover, the land management to use long term conservation measures not a adopted by people since the people right on land are insecure and as a result that they only grow plants (crops) for short period of time.

Population growth is another factor in affecting land use pattern. Besides to the high growth rate in the watershed, as a result of which people migrated from the upper watershed to the lower watershed. The area of the lower watershed, in which once covered by forest was cleared for cultivation Moreover, the ground land, bush land/ scrubland also converted to cultivation.

In general, more fragile land is brought under cultivation.

Furthermore, the population increase causes the rise of demand for agricultural and the increasing demand of fuel wood, construction materials etc. This lead to the high deforestation rate. The rate is aggravated since no plantation activities on the removed woods. To produce more, people urged to cultivate the marginal land. In communal grazing system also, less attention is given on the management.

The other factor is the personal to the individual, which depends on age, personality and ability. Most of the people are illiterate that the know how of maintaining deforestation, intensive cultivation and on the varieties of crops to grow. Thus they only produce what the ancestors were used to produce. Moreover the use of means of cultivation is also similar to the tools which was used in past time such as hoe, ploughing by ox and etc.

The objective of land user is to produce subsistence. In subsistence production, the farmer needs is only to meet the basic need and not to produce surplus production. In cases when they produce surplus production they may use money for construction of corrugated iron sheet for their house and purchasing of ox.

The surrounding people to which products are sold are also poor. Nor cash crop is grown in the watershed, particularly in the upper watershed. The low income of the pwople intum cause low productivity. It also enforce the people to look for another source of income, on of which is selling of wood by cutting the tree. tcollection of w o he

To summarize the present land use and land covers is the result of the above stated factors. In future If these states continues, namely as population growth, present land management etc much more land will be degraded very seriously that may be irreversible.

2. Causes of Water Logging

In the lower watershed irrigation is practiced. Two weirs have been constructed. One by Lutheran and the other by Chinese which was remained uncompleted due to various reason. Water logging is occurred in the area due to unproper functioning of the structures and the misuse of the people. Such as,

a) Seepage of unlined canal. There

is no proper drainage system and improper leveling.

b) Poor management of water such as farmers watering their land excessively which is arise by wrong impression that more water may result more crop yield.

c) Moreover the soil is marked by poor drainage because in some of the top soils, clay content is high.

d) The tillage system of the farmer also create obstruction to the flow of irrigated water forming depression land creating obstruction to the flow in the farm by way of depression.

3. Causes of Sedimentation

Sedimentation is affected by different factors of which the main ones are:

*Land use:-*The land cover of the upper watershed particularly the steep slope is deforested and devegetated. There is low use of conservation measures and the practice of cultivation is out molded.

In consequences, there is no interception of rainfall and splash erosion is formed. There is also hindrance or barriers for the run-off, which scours the soil surface. Furthermore, infiltration is hindered. High surface runoff is very high at the lower watershed which abundantly form sedimentation (carrying large amounts of particles, boulders etc)

Soil type:- Sandy soil is more detachable compare to clay soil (Sureh, 1997. In the steep slope, the Texture is more sandy and thus the removed rate is high.

Catchment size:- In the upper watershed, the surrounding area in which river flows is very steep and the riverbanks also surrounded by steep and narrow gorges. In subsequent the peak flow is high and the velocity of the water is also high. Since the erosivity of a river is affected by velocity which is in turn the function of slope, vegetation cover, seasonality of flow and volume of water and permeability of rocks.

Climate and Rainfall

In the lower watershed, there is heavy storm, which resulted high rainfall intensity. It causes more run-off yield and the consequent great detachment of soil particle. Ultimately the sediment yield is increased.

Proposed Management Plan Of The Hare Watershed

There are different problems on resource utilization of the watershed of which the problem of degradation is serious problem as witnessed by the low level of different nutrients, imbalances of nutrients, production, shallow soil depth, water logging, deforestation, sedimentation are few among others.

It is obvious that there is areal variation of the extent and type of the problems and the corresponding indigenous measures in the watershed. In the upper watershed, the major problems are leaching and removal of soils. While in the lower watershed the major problems are water logging, flooding, and silitation of weirs and canals. Likewise, the activities of the people in the upper watershed are more concerned to halt and reduce erosion. They practice mulching, strip cropping, and terrace since the long period of time. Although, the practices are not effective to control the problem. On the other hand in the lower watershed, people have taken very little initiative to control the problem, because the area is less affected by degradation. Besides, their perception of the problem is also very low.

In general however, the present activities of the farmers in the watershed to manage the problem is very low. Moreover, there have been only insignificant activities have been so far carried out to solve the aforementioned problem on the government organization and non-government organization as well. If strong involvement had been there, degradation problems would not been a threat for the living condition of the people.

Besides to the needs of understanding different measures on the aforementioned problems it is also important to consider other problems that causes directly or indirectly the degradation problems. Including among others water shortage, land shortage, high population pressure, low productivity and others.

Therefore, in the watershed different comprehensive strategies are required to solve in accordance with the problems which are occurring in different land units of watershed Furthermore the successful management of watershed management plan, the following points need to be given high attention.

It should give emphasis to the socio-economic condition as well (not only on the physical effectiveness of the practice) the practice in order to be adopted to the farmers it should meet the immediate needs in production. And hence it should beneficial in short term that is yield to increase income rising.

Participation to be encouraged in all levels of planning.

Attention should also be given to the land tenure systems.

Practical applicable at the knowledge of the local people. It is also to give incentive, subsides and application of food for work. But these matters are carefully thought out, planned and implemented because even in maintenance the people need food. And also promotes dependency.

1. Strategies To Mitigate The Hare Watershed Problems

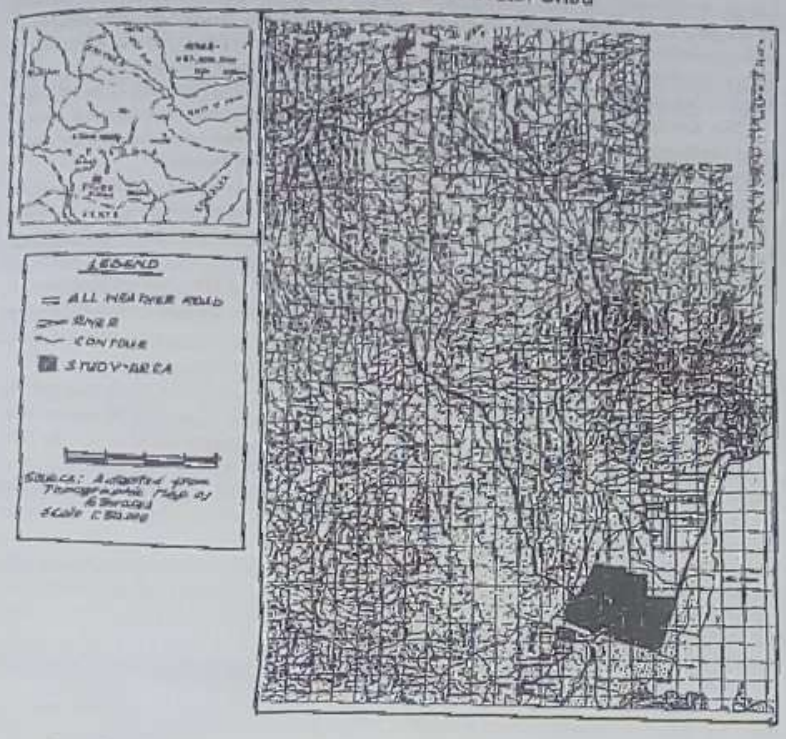
The major problem in the Hare watershed is soil degradation, which is mainly caused by land use pattern. The following is the three major categories of practices of soil water conservation. Moreover these practices are important to restore, maintain and sustainable utilization of resources.

A.Plant management practice refers using the plant and cover which include fertilization, crop rotation, revegetation, stubble mulching, compost, manure, agroforestry, water harvest, drought resistant crops and others.

By using the plant and cover influences. These practices may be very effective, relatively simple and cheap. Cover management is important to influence erosion hazard and often it can be used to some degree for soil conservation. Crop residue mulch applied at a rate of about 10+/ha/yr reduced soil-loss on slopes by up to 15 percent. Mulching is also helping to maintain organic matter content, improve soil physical properties, and maintain soil pH.

In conditions where agricultural land-use can be combined with the

Fig 1. location Map of Hare Water Shed



growing of trees,

Agroforestery techniques may be employed.

The following are options to be presented:

Crop rotation:- is a system of growing different crops one after another on the game piece of land. Crop rotation has significant benefits to reduce erosion by covering, increase the organic matter of the soil and most importantly, increases nutrient the subsequent increment of Nitrogen fixation. The productivity of the soil will rise.

It is implemented in farmland lower in slope is below<15%. The crop rotation my follows as in the I" year cereal wheat) and in the next year leguminous plants (barely peas and beans.

In order to apply, select five active, volunteer farmers, preferably who, used to practice crop rotation Train and if possible arrange four to places (like Konso) where crop rotation practices is tradition. After implementing, immediate supervision is need. In evaluation collect the data before practice and the crop after the newly crop data. At the end display to all people explain to them and to held discussion.

Mulching :- is practice to leave crop residues on field and mix with soil during ploughing. It is important as a cover these to protect soil erosion and in protecting the surface runoff. More importantly, it adds the organic matter of the soil and upper watershed the soil nutrients and stability the soil structure. The application is similar to crop rotation.

Contour strip cropping: In areas where terrace is not practiced and slope is divided into different small segments. The slope range 5-15% and width 15% Application.

B. Land Management Practices

using land layout and soil management These practices are used in addition to plant management. They may reduce erosion effectively. It includes contour tillage, contour strip cropping, minimum tillage, land layout

B. Structural Practices: using small structural works. Such as terrace, banks, gully filling contour terraces, absorption terraces, bench terraces, broad based terraces and narrow-based terraces, contour terraces, retention terraces, graded terrace, Fanya -Juu

The major components of the strategies other than the package of treatment, it includes among others:

Construction of an dam in the lower watershed

Provision of underground conveyance of irrigation water to the farming field

Land capability for effective use of irrigation water

Provision of improved seed and water

Construction of village society in the watershed.

I I. Effectiveness Of Plan

In the long term plan and activities for the sustainable land management, solutions need to be looked for the factors other than (natural management of land) in soil degradation.

These factors are population growth, government policy people awareness and the like.

Population Growth.

The watershed population growth is very high which is as the case of the whole country. The solutions are the increase usage of family planning method, make access of contraceptives, and creating awareness of the people on the benefits of the family planning.

Government Policy

In order to secure the land property right, the farmers to decide by themselves. Moreover, there should be clear guideline policy on the forest and management of grazing land

People Awareness

Some farmers don not give attention for the problems which arise mainly due to low awareness about the natural resources deterioration and management. Thus the need to rise the awareness in this regard via education and making to participate in planning.

Conclusion And Recommendations

The panning processes particularly in land use planning, by which physical, social and economic factors are assessed in such away as to encourage and assist land users in selecting options that increase the sustainable productivity and, meet the needs of society. Despite of the different steps and procedures involved in land use planning, the following are the most important steps to be followed:

1. Description of the watershed
2. Identification of problems
3. Determining of alternative solution
4. Decide which is the best alternative and prepare the plan
5. Put the plan into action and evaluate.

The deterioration of natural resources in an area can be obtained and the total resources properly developed only by adopting the watershed approach. The basic unit of development is a watershed, which is a manageable hydrological unit. In this approach, development is not confined to agricultural land alone, but covers the area, starting from the highest point of the area (ridge line) to the outlet of the nalah or the natural stream.

The Hare watershed altitude ranges from 1200m to 3480m. The topography is also marked by very steep slope to flat. The subsequent of which resulted in the watershed to be characterized by different rainfall, temperature, natural vegetation, land use pattern, soil and types of crops growing in the area varies.

In addition, the problems of the watershed vary from place to place. In the upper watershed the dominant problems are soil erosion by water, which affect the availability of nutrients, soil depth and organic matter. Leaching is also another problem in the area that cause the reaction of the soil to be acidic. The subsequent impacts of which are reducing the availability of nutrients, declining in the water holding capacity and the problem of root anchorage are few among others. Ultimately, the agricultural productivity is declined and resulting of famine. The major problem of the lower watershed is deterioration of drainage including water logging, sedimentation and flooding. The other major problem is the poor management of water and the erratic rainfall.

The ameliorative measures such as crop management, land management and structural works to be determined based on the problems identified in the watershed. Moreover, the land capability classification and the problems on each class need to be determined. Then identifying solutions from the alternative options, which should include the indigenous knowledge of soil and water conservation. In all cases, that is from the very inception of the plan to implementation the local people should be participated.

The causes of the problems viz. land cover and land management, and socio economic factors such as land security, poverty and population growth, which are components of the problem, require urgent solutions.

In the watershed the area of study that needs investigation is the water management and the design of the appropriate plan of implementation. Moreover, people perception of problems of water management and their knowledge should thoroughly examine.

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Duplication of Hydrogeological Investigations: The Case of Borena Zone

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Abstract

The Zonal Water Department, NGOs and international organizations conduct both hydrogeological and geophysical investigations before drilling, in order to minimize the failure rate. In addition to the above, the Ethiopian Institute Of Geological Survey has conducted extensive hydrogeological, engineering geological, geophysical and geological investigation in the lowland area of the Borena zone, but there is neither proper management nor dissemination of the findings and well data. This has resulted in a duplication of efforts, wastage of money and consequently, limited water resource development in the zone.

Borena zone is one of the twelve zonal administrations of Oromiya Regional State and located in the southern tip of the country. Topographically, the zone is classified as highland and lowland. The lowland area consist 62.5% total land area of the zone and characterized by semi-arid and arid climate and inhabited by pastorals, agro-pastoralist and farmers. Basement complex, Tertiary Volcanic and recent sediment (alluvial and elluvial) covers the area. Ponds, traditional dug wells and bore wells are the source of water both for domestic and livestock use. Recurrent droughts in the area dry most ponds and traditional dug wells; leaving bore wells as the only possible source to overcome the long-term water supply problem. However the limited number of wells in the area hasn't yet satisfy the need, so government, NGOs and international organization like UNICEF, financially assist the drilling of new wells to solve both the existing and future water supply problems in the area. Hard rocks (basement and volcanic) dominate the lowland area in which groundwater occurrence is controlled along fractured and weathered zones. The geology and climatic condition of the area requires the systematic location of well sites in the area before drilling.

1 Background

Borena zone is one of the 12 zonal administrations of Oromiya Regional State and located in the southern tip of the country between 3°36'-6°38' north latitude and 36°43'-41°40 east longitude. It has an international boundary with the Republic of Kenya in the south, regional boundary with South Ethiopia Peoples Regional State in the west and north west and Somalia regional state in the East and zonal boundary with Bale zone in the north east (fig1).

Topographically the zone can be classified as highlands having an altitude above 1500m a.m.s.l and lowlands having an altitude below 1500m a.m.s.l. 62.5% of the total land area of the zone is categorized as lowland with semi-arid and arid climate and inhabited by pastoralist, agro-pastoralist and farmers. Ponds, traditional dug wells and bore wells are the source of water in the lowland area of the zone.

The geology of the zone can be classified as, basement complex, Jurassic to Cretaceous marine secessions, Tertiary volcanic and recent sediments (elluvial and alluvial), basement complex is the dominant rock unit in the lowland area of the zone. In hard rock (basement, limestone and volcanic), the movement and occurrence of groundwater can be significantly affected by fractures. Increase in the number of interconnected fractures in given volume increase the capacity of the rock to store and transmit the groundwater. Therefore, if fractures are mapped and correlated with areas of high groundwater potential, well site selection can be improved.

Borena zone is one of the drought prone areas in Ethiopia. Ponds and dug wells dried-up frequently in the lowland area because of recurrent droughts. Drilling of shallow wells by government, NGOs and international organizations is the proposed solution to overcome water supply problem in the area. Hydrogeological and geophysical assessments are conducted before drilling work, to minimize the failure rate. The Ethiopian Institute of Geological Survey conducted extensive hydrogeological, engineering geological, geophysical and geological investigation in the lowland area of the zone, but management and dissemination of the finding and well data is lacking. This has resulted in a duplication of efforts, wastage of money and, consequently, limited water resource development in the zone.

2 .Objective

The objective of this short paper is to highlight the duplication of hydrogeological assessment in the lowland area of Borena zone by different organizations as a result of inadequate data dissemination and management problems.

3. Methodology

The following methods are used for collecting information:

- Reviewing hydrogeological and geophysical assessments already conducted in the area and their finding.
- Discussions with hydrogeologist at the zonal water department and various NGOs engaged in water development in the zone, and information they have regarding the previous assessments and the method they use during the assessment work.

4. Discussion

Living in the information era, information technology such as Internet, satellite receiver's etc, play a key role in our daily life by transferring information. Geological and

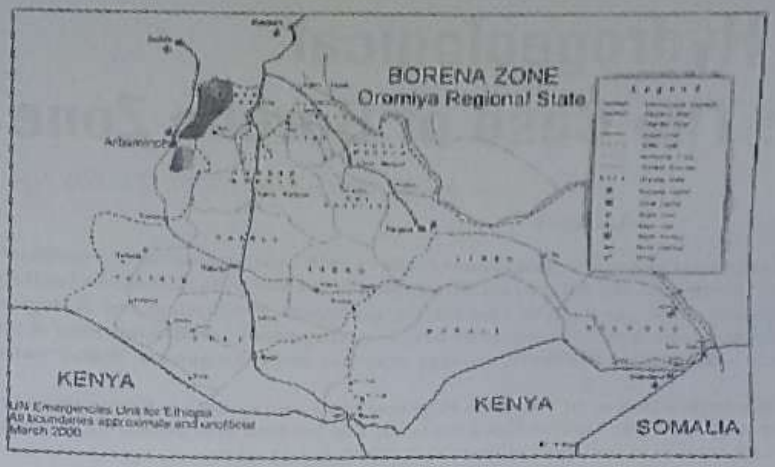

Fig 1: Location map

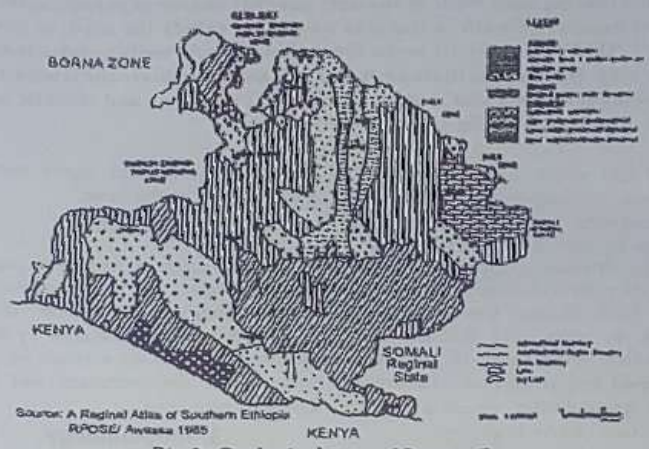

Fig 2: Geological map of Borena Zone

hydrogeological maps of different scales, water well data (well depth, static water label, well yield, aquifer description etc) and water quality data can be navigated through networks in developed country's, users have free accesses to information they need. Because of our development stage and socioeconomic status, one can't insist on having the above system to disseminate the existing hydrogeological and geological data's. However it is possible to disseminate the information in hard copy form (reports and maps) by responsible organizations, to development agencies and improve information exchange.

The Ethiopian Institute of Geological surveys has conducted several geological and hydrogeological assessments in different parts of the country. Lowland area of Borena Zone is one of the area where detailed hydrogeological assessment was conducted by the institute, but there is no dissemination of the findings, as a result similar hydrogeological and geophysical work was done by the zonal water department, NGOs and international organizations.

4.1 Previous Assessment Work

The following hydrogeological and geological assessments were conducted in the lowland area of Borena zone by different organizations.

· ***AGROTEC/CRGSEDES Associate,1974. Southern Rengeland and Livestock's Development Projects: Part II studies and surveys, volume4. Surface hydrolog yand Geohydrogeology:*** The objective of the assessment was to identify groundwater and surface water potential of the area for livestock's development. During the assessment, inventory of existing water source (dug wells, spring and ponds) water sample collection for chemical analysis and test well drilling was preformed, based on the conducted assessment, rock units were classified into different aquifer types and an accompanying geological map at 1:500,000 scale was produced.

· ***SBSIBE ALEMNH AND DR. SIMA JIRI, 1988: Hydrogeology and Hydrochemistry of Sololo sheet (NB37-2) and Moyale sheet (NB37-3), Ethiopian Institute of Geological Survey.*** The assessment was conducted to produce hydrogeological map at 1:250,000 scale. The map shows classification of rock units into different aquifer groups and distribution of water types in the area. The assessed area covers Moyale woreda and most of Dirre woreda.

· ***SBSIBE ALEMNH AND DR. SIMA JIRI, 1989: Hydrogeology and Hydrochemistry of Yabello sheet (NB37-14), Ethiopian Institute of Geological Survey.*** The assessment was conducted to produce hydrogeological map at 1:250,000 scale. The map shows classification of rock units into different aquifer groups and distribution of water types in the area. The assessed area covers, Yabello woreda and part of Arero Woreda.

· ***Getahun Kebede et.al, 1988. Hydrogeology of Dawa Basin and Laga Sure, Ethiopian Institute of Geological Survey.*** The assessment was done by using aerial photo and satellite image and field work, finally a hydrogeological map at 1:1,000,000 scale, which shows the classification of rock units into different aquifer types was produced.

· ***Genale-Dawa River Basin Project 1996. Hydrogeology, Engineering Geology and Geothermal Department, Ethiopian Institute of Geological Survey.*** The project lasted for four years (1993-1996). The objective

of the project was hydrogeological, engineering geological and geophysical investigation of drought affected southern Ethiopia. The lowland area of Borena zone is covered by yabello sheet (NB37-14), Sololo sheet (NB37-2), Moyale sheet (NB37-3), Chew Bahir sheet (NB37-15). The assessment covers Moyale, Dirre, Yabello, Arero and part of Teltele woredas. The following results are found after completion of the project:

a)Hydrogeological: A hydrogeological report for each sheet with accompanying map at 1:250,000 scale was produced. The map gives information about:

- Classification of rock units in to different aquifer type and/or the assessed area in to different groundwater potential.
- Distribution of inventoried water points(dug wells, springs and bore wells)
- Location of sites selected for drilling and/or detailed investigation.
- Distribution of water type.

In addition to the map the report elaborates, aquifer development, mode of groundwater occurrence, factors, which control quality of water and suitability of water for different purposes.

b)Engineering Geology: Engineering geological report for each sheet with accompanying map at 1:250,000 scale was produced. The map details:

- Selected micro-dam sites.
- Classification of rock units, according to their mass strength.
- Location of selected materials (for different construction).

c)Geophysical: Even if geophysical investigation was conducted at limited sites, the interpretation and geo-electrical section of the investigated sites are included in the report.

- ***Model Project on Isotope Hydrological Investigation, Southern Ethiopia, Regional Project RAF/8/022, Ethiopian Institute of Geological Survey, August1997.*** The objective of the project was application of Isotope Techniques to solve major hydrogeological problem in arid lowland area of Borena zone. In particular, the method, the mechanism and the source of recharge to aquifer, which can't defined by conventional hydrogeological methods. The assessment covers, Moyale, Dirre, Yabello, part of Libean and Arero woredas. After completion of hydrogeological and Isotope analysis result, the project was finalized with the following finding.

i) Delineation of zones of recent recharge: The conventional hydrogeological assessment in the lowland area identified two major types of aquifers. The isotopic investigation confirmed the difference in the mode of recharges between the aquifer below lacustrine deposit and fractured granite-gneiss below sand (soil) cover. It is assumed that fast recharge is taking place in locally fractured zone of rocks unlike areas covered by calcareous sediment.

ii) Delineation of palaeowater: The study was concentrated on existing supply wells, a few specially drilled wells and springs, confirmed except one well (Melbena 37Pmc), shallow groundwater circulation on sand and gravel aquifer confined by lacustrine sediments. Similarly the fractured granite-gneiss, which underlies most of the area, will not facilitate significant deep groundwater circulation. There fore, palaeowater doesn't represent an important component of the overall groundwater resource in the area.

iii) Identification of interaction between aquifer: Since sampling points are widely dispersed, it is not in general possible to assess interaction between aquifers. The small but distinct separation between the stable isotopic signals of out cropping fractured rock aquifers and aquifers covered by lacustrine deposits reveal that two aquifer systems do not significantly interact at present.

iv) Assessment of pollution risk: As isotope data shows most groundwater water samples in the area is subjected to significant present–day, local recharge it is prudent that all groundwater supply points have to be regarded as prone to pollution from the surface.

- ***Mogoes Tigabe, August 1996. Geophysical exploration of a buried river valley for groundwater in the southern Borena zone. Ethiopian Institute of Geological Survey.*** The survey was conducted around El-gof to delineate the extent and trend of a buried channel. The gravity map show the low gravity valley at the central part of the area and interpret this as a result of the NW-SE buried river where as the gravity high in the northern and southern part may me attributed to shallow bedrock and possibly from barriers with in channels. The survey also shows that; the buried channels have a meandering pattern with a high degree of sinuosity and exhibits undulation (shallow and deep) along its course. The finding of this investigation can be used as a model for the rest of the area covered by lacustrine and under lay by gravel and sand aquifer as well as support the finding of isotope investigation.
- ***Regional Geology Department, 1992/93.Geological Mapping of Sololo and Moyale Sheet. Ethiopian Institute of Geological Survey.*** The objective was geological mapping of the area and producing a map at 1:250,000 scale.
- ***Assessment by Zonal water department, NGOs and international organization.*** Since its establishment, the zonal water department was conducting hydrogeological and geophysical assessments at targeted PAs, in order to select the potential sites. They conduct assessments by using top map at 1:50,000 scale and field observations, this was due to the absence of previous hydrogeological and geological work conducted by other organization at the zonal level. NGOs working in the area used similar methodology.

4.2 Data Management

Establishing relationships between features identified in remote sensing data, bore well records (well location, well depth, static water levels, geological logs, well yield, water quality etc) and other hydrogeological phenomena are important to minimize the failure rate of new well drilling. Good bore well data management is an dispensable tool for selecting potential sites. As observed in recent assessments, there is no systematic management of previously drilled bore holes data at zonal water department. Even it is difficult to get information of 86 wells

drilled in the lowland area of the zone during 1994-1996, emergency program, which was assisted by UNICEF.

To overcome the above problem inventory of existing rural water supply schemes in the zone was started in 2000 by zonal W.M.E.R.D.D. Up to July 2001, 375 schemes have been inventoried (231 dug wells, 112 bore holes and 32 springs). Out of 112 bore wells, only the depth of 49 bore wells is known. The rest bore wells data such as: grid references, elevation, yield, static water label, geologic log data, pump test data and chemical analysis of wells were not found for all bore wells. This is due to the absence well data management until 2000.

4.3 Impact of the absence of data dissemination and management

Drilling shallow and deep wells is the only sustainable source that can improve water supply problem in the lowland area of Borena zone, which affected by recurrent drought. Climate and geology of the area obligate the zonal water department and other organizations developing groundwater in the area to conduct hydrogeological and geophysical investigation before drilling to minimize failure rate. As mentioned in the previous section, the Ethiopian Institute of Geological survey conducted several hydrogeological assessments and produced accompanying maps. If these maps were disseminated to end users, like the zonal water department, they can be used to delineate groundwater potential areas and recommend the possible source of water where groundwater potential is poor (cistern and sub-surface dam), for selection of geophysical method to be used at different places, type of well to be drilled (shallow or deep), for designing drilling methods (percussion or Down the hole) and drilling fluid to be used etc, during project planning stage. But there was no dissemination of information's. So in order to get the above information they conducted the assessment each year at targeted PAs, without considering the regional hydrogeologic and geologic condition. As a result, work is duplicated and money is lkost, which can be used to develop additional wells rather then spending for assessments period. It can take log time to understand the groundwater potential of the lowland area because of target oriented assessment approach.

The absence of systematic management of previously drilled bore well information is also another major problem, which has equal effect as dissemination of data in water resource development. Bore well data is crucial information it can be used for planning water development based on area covered, for identification of potential zone based on the yield and depth of the well, and maintenance of the scheme based on pump position, casing arrangement etc. But there is no such systematic data management, so it has similar effect on water development.

In addition to duplication of work and wastage of money, the absence of dissemination of assessment finding like, the existence of recent recharge to the aquifer, caused criticism by different government organization and NGOs on water well drilling programs, because they think that pumping groundwater can deplete the groundwater potential in the area with in short period.

5. Conclusion and Recomendations

Lowland area of Borena zone is characterized by semi-arid and arid climate and dominated by basement complex. Recurrent drought dried-up ponds and traditional dug wells. Drilling of shallow and deep wells was the proposed solution to overcome the water supply problem, hydrogeological and geophysical assessment was conducted by zonal water department and other organizations. By giving due attention the Ethiopian Institute of Geological Survey has conducted detailed hydrogeological assessments in the lowland area of the zone and produced maps and reports, but the output of the assessment was not disseminated to development agency. As a result they spend a lot of money each year for assessment, which caused duplication of work and wastage of budget. Similarly there is no management of well data until recently conducted inventory, at the zonal water department level. Therefore proper dissemination of hydrogeological, geophysical and geological assessment findings by responsible organizations to the development agencies, such as zonal water departments, regional water Bureaus and NGOs and their systematic management of bore wells data is recommended. These will help accelerate sustainable water development by using the budget efficiently, organize data for development and researcher etc.

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Application of Genetic Algorithms in Water Resources Engineering

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Abstract

The paper demonstrates that genetic algorithm (GA) can be used as an alternative approach to operations research in solving mathematical programming problems. The author describes the concept of genetic algorithm as relatively new and promising search and optimization technique. Two examples were introduced in the paper that clearly emphasize the advantage of GA approach. It has been observed that GA formulation presented in the paper significantly speeds up the convergence and leads to better solution.

Literature review

Genetics algorithms are search and optimization technique based on natural evolution, Goldberg [1].It was first introduced by Holland [2] in 1975, the Genetic algorithm is the most widely studied and applied EP technique. GA originated in the United States almost simultaneously as the ES did in Europe. In his doctoral dissertation Bagley[3] considered

Initial ideas also pursued by Holland and later by Goldberg. In the mean time it is estimated that the publications on GA outnumber those on ES by more than 100:1, Schoneburg and others [4].

Genetic Algorithms (GA)

A salient feature of GA is the binary coding. Any variable, may assume but 0 or 1, thus constituting a bit. This offers an obvious advantages for efficient computations since it corresponds to the code of machine language and the genetic operations are performed straight-forward on bits. A brief description of one of the many possible GA implementations is given here:

(I) Map each design variable onto a binary string, e.g.[0111001]. The string can be of any length, and can represent actual discrete choices, or discrete values of a bounded continuous variable. For example, an 8 bits string represents up to 2 discrete values for a design variable. The complete design may be represented by a single long binary code consisting of all strings placed end to end. This long string is equivalent to a chromosome in nature.

(II) An initial population of individual designs is created by random process. Simply choosing each bit to be 0 or 1 at random is the simplest procedure. A population size between about 10 and 100 is adopted.

(III) The objective function (i.e. cost, benefit, reliability or some other relevant measure) is evaluated for each population member. If a member violates a constraint, a graduated penalty is imposed. The fitness is evaluated for each member, depending upon the objective function value. A fitness function giving 1.0 for the best member of a population and 0.0 for the worst member.

From the exiting population, a complete new population of solutions (the next generation) is formed using the following rules of reproduction.

Selection

Selection is the survival of the fittest process. Although the selection operator can be implemented in variety of ways, there are two commonly used techniques: proportionate selection, Goldberg[1989], and bit tournament scheme. Proportion or roulette wheel (as it is also called) scheme gives each solution an appropriate segment in weighted roulette wheel; the size of the segment is proportional to the fitness of the solution. The chromosomes with better fitness have larger segments and therefore greater probability of selection. In proportionate selection scheme each individual for reproduction is chosen randomly. In tournament selection, every time we want select an individual for reproduction, we choose two and the best wins with some fixed probability (0.9). This scheme can be improved by using more individual in the competition. It was shown that tournament selection was much more effective than proportionate selection scheme, Simpson [1994]. Further speed of convergence is achieved by discarding previously defined number of chromosomes (usually25%) with lowest fitness rates from the current population.

Crossover

Crossover is the main genetic operator and consists in swapping chromosomes parts between the individuals. The simplest crossover operator is implemented by selecting a random crossover point in the chromosomes. And swapping the genes that reside between the crossover point and end of the chromosome (Fig.1.b.). Crossover is not performed on every pair of individuals. Its frequency is controlled by a crossover probability. This probability should have a large value (typically 0.8) Just described is one point crossover. In order to make search more efficient, two crossover point were implemented. It was shown by Booker[1987] that two crossover points exploration over exploitation and decreases the possibility of premature convergence and happens so often in implementation of GA.

Mutation

Mutation is the last genetic operator. Most common method is bit wise mutation. It consists in toggling a random bit in the individual (Fig.1.c). Mutation is an insurance against the loss of potentially useful genetic material. For Example if ones or zeros at a particular gene are lost, for all the chromosomes in a population,

They could never be returned without the mutation of this gene. This operator should be used with low probability (typically 0. 01).

Besides global exploration, efficient optimization technique should do some extra search in the vicinity of present solutions. The adjacency mutation provides necessary fine adjustment during the search Simpson and Goldberg [1994]. Unlike bit wise mutation, This type of mutation is done on the gene (variable) level. Part of the chrosomes(genes) That represents the coded value of the variable is chosen randomly, and adjusted at higher or lower rate. Adjacency mutation is implemented with much higher probability(typically 0.5).The Probability of choosing the direction of adjacency mutation can be biased or unbaised in either direction in the choice list.

The simple behavior of GA hides a powerful processing. The combination of selection, crossover and mutation leads to increase in the number of individuals that posse's small. Tightly coupled blocks of bits (building blocks) leading to good performance Holland [1992].These blocks are replicated through selection and combined or separated by crossover.

Basic Genetic Algorithm Procedure For Solving the Linear Programming Problems

Genetic Algorithm (GA) is based on the natural selection process .The process starts with a randomly created first generation of population. To simplify the process, the population is usually kept at a constant size for the entire evolutions every individuals in a generation represents one solution and consist of one chromosome with number of genes. Each chromosome is then evaluated for its fitness. The fit chromosome has a better chance of surviving in the next generation. Genes are exchanged through the crossover process and diversity is added in to the population by the mutation process. The process is repeated over several generations and the overall best solution is used.

Linear Programming:

Problem Defination:

1. Objective Function

Maximize $P(X_1, X_2) = 50X_1 + 60X_2$

$$8X_1+4X_2 \le 40$$
$$4X_1+5X_2 \le 40$$
$$50X_1+13X_2 \le 200$$

Procedure

The first part of the chromosome contains the binary representation of X_1, while the second part represents X_2. Let a_k and b_k be the lower and upper bound of X_k. The range r_k becomes (b_k-a_k). If d is the number of decimal places in each variable, then the number of genes required for binary representation of X_k is [$\ln(r_k \cdot 10^d)/\ln(2)$].

The first generation is randomly created by filling all genes slot with zero or one. Each chromosome is evaluated for its fitness in order to determine the chance of being selected in to the next generation. From each chromosome, the binary representation of each variable is converted to corresponding real number. These real number after divided by 10^d are entered in to the objective function to determine the value of the function P. Each constraint condition is then evaluated. Initially, the fitness is set equal to the value of the function P. Thus the higher the value of function P, the higher is the fitness. For each violation of the constraint conditions, the fitness is reduced by dividing the fitness by a user specified extra penalty. It also could occur that the value of X_k turns out to be greater than the user–specified upper limit If this happens, the fitness for that chromosome is also reduced by dividing the fitness by same extra penalty. Chromosomes are selected into the next generation

Based on their fitness. The process is similar to creating a spinner in which a chromosome with a large fitness occupies a large area in on the spinner. The spinner is then spun for the number of population to select a group of potential parents. These potential parents then go through the process of crossing (in which the genes are exchanged) and the process of mutation (in which the genes are altered).The process is repeated for the number of generations specified by the user. The best solution is then presented.

Results

Twenty consecutive runs were made with different combination of population size; crossover probability, mutation probability and user specified extra penalty value.all runs were made for hundred generations with two decimal places for Xs. The result of best run is shown as follows. The maximum P obtained was483.3 as compared to 483.33 by the operations research linear programming approach(Pitcher, 1976). From these 20 consecutive runs, 19 runs give results with 1% of the optimum solution.

Water distribution network

Water distribution network is designed to be capable of satisfying the customer requirements, namely to meet the pressure requirement at predefined nodal points. It is assumed that the layout of the network is predetermined and the demand and required pressure are specified. The task is to choose the pipe diameters, from the range of available pipe sizes in the manner that leads us both feasible solution (pressure requirements are satisfied) and least cost solution. Each value from the choice list must have its unique binary code presentation. It should be noted that the dimension of discrete space of possible solutions coincide with number of pipes with unknown diameters.

The starting population is randomly generated set of chromosomes. Each chromosome represents a possible combination of pipe sizes; hence a possible solution of the problem and hydraulic analysis of the network is done to determine if demands for node pressures are violated. Penalty is usually a linear function of degree of violation of pressure constraints:

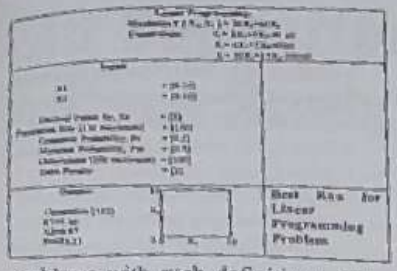
$$\text{Penalty} = \sum (\Pi_k^{min} - \Pi_k).Cp \qquad (1)$$

Where: k- nodes where the pressure constraint are not satisfied, Cp-specific value of penalty function ($/m) and Π_k, Π_k^{min} – calculated and required piezometric head at node k.The total cost of network (C) is written as sum of the material cost and penalty cost:

$$C = \text{Cost} + \text{Penalty} \qquad (2)$$

Where material cost is the sum of new pipes costs.

Fitness is commonly defined as the inverse total cost function Simpson and Dandy[1994]. However there are



Best Run for Linear Programming Problem

problems with such definitions, especially with later stage of calculations when the string are constructed of very similar genetic materials

And their fitness is similar as well. To avoid this problem the fitness is calculated by linear scaling the total cost in [0 1] domain. One should recall that the selection operator is implemented in the manner that the part of population (25% of the worst chromosomes) is discarded. The fitness of the i^{th} chromosome (fi) is calculated by scaling its total cost (Fi) inside the rest of the population (F'):

$$f_i = \frac{|\max(F') - F'i|}{\max(F') - \min(F')} \qquad (3)$$

Linearly scaled fitness function improves the convergence of the GA and it seems that the improvement does not lead to the loss of diversity which was recognized as a prime reason for the premature convergence.

GA formulation that was used in following case studies is as follows:

- Bit tournament selection is implemented on reduced population as 25% of worse chromosomes are discarded firstly. Fitness of each chromosome is calculated by linear scaling the total cost inside the rest of population.
- Reproduction with two crossover points is used.
- Bit wise and adajancey mutation were used simultaneously.
- Adjancey mutation is not biased in either direction (P_m 0.5) (upward or downward) through the choice list.

Case: The New York City Water Supply Tunnels:

Many authors have tested different optimization models on this example. It's a gravity single reservoir system with large diameter deep rock tunnels. The primary water supply tunnel system is shown in Figure. Characteristics of the network are given in Table1, and require minimum piezometric heads and demands are presented in Table2. Hydraulic analysis shows that the existing system cannot meet estimated future water demands that are node pressure constraint couldn't be satisfied in nodes 16, 17, 18, 19 and 20. Proposed expansion of the system included construction of the tunnels parallel to the existing ones to enable the system to meet increased water demands Murphy, Simpson, Dandy [1993].

The HazenWilliams head-loss formula for a pipe (metric units) is shown below:

$$Hf_{-10.675}[Q/C]^{1.852} D^{-4.870}L$$

Where; Q= Pipe flow in m^3/s
D = Pipe diameter in m
L = Pipe length in m

Available diameter for new tunnel is presented in Table 3.Choice list consists of 15 values plus zero that relates to the case that existing tunnel is not duplicated. Corresponding costs and binary code are also presented in the Table 3. A Hazen-William

Roughness coefficient C=100 is assumed for all pipes. It should be pointed out that metric unit is used in this paper, unlike most of the previous studies where calculation is done using imperial unit system. Hydraulic analysis has shown that differences that occurred due to conversion were negligible (differences in pies metric heads were below 1 centimeter).

The cost function for new pipes established by Schaake and Lai (1969) was used here:

$$\text{Cost} = (1.1/0.3045).1.(D/25.4)^{1.24}$$

Where cost is in dollar, length in meters and pipe diameter (D) in millimeters

The crucial point in the optimization process is to implement an efficient network solver. For the purpose of this study, the program for solving the looped system is written in C language and integrated with GA optimization solver. Equations are set in terms of

Unknown nodal heads and Newton-Raphson method is implemented for solving the system of non-linear equations. It is well known

Pipe	Start node	End node	Length (m)	Diameter (mm)
1	1	2	3536	4572
2	2	3	6035	4572
3	3	4	2225	4572
4	4	5	2530	4572
5	5	6	7621	4572
6	6	7	5823	4572
7	7	8	2926	3353
8	8	9	3810	3353
9	9	10	2926	4572
10	17	9	3414	5182
11	12	11	6430	5182
12	13	12	3719	5182
13	14	13	7346	5182
14	15	14	6431	5182
15	1	15	4724	5182
16	16	17	8047	1829
17	12	18	9510	1829
18	18	19	7315	1524
19	11	20	4389	1524
20	20	16	11704	1524
21	9	16	8047	1829

Table1. Pipe data of distribution network:

Node	EL (m)	Demand (m^3/sec)	Diam. (mm)	Cost ($/m)	Binary code
1	91.44	0	0	0	0000
2	73.77	2.83	914	2001	0001
3	77.72	2.52	1181	4449	0010
4	77.72	2.5	1524	6771	0011
5	77.72	2.5	1829	9129	0100
6	77.72	2.5	2134	11496	0101
7	77.72	2.5	2438	13857	0110
8	77.72	2.5	2743	16218	0111
9	77.72	4.81	3048	18585	1000
10	73.77	0.69	3353	1926	1001
11	73.77	4.81	3658	1731	1010
12	77.72	3.12	3962	1863	1011
13	77.72	3.12	4267	20073	1100
14	77.72	2.62	4572	22440	1101
15	77.72	2.62	4877	24801	1110
16	77.72	4.81	5182	2618	1111
17	82.19	8.63	-	-	-
18	73.77	3.32	-	-	-
19	77.72	3.32	-	-	-
20	77.72	4.81	-	-	-

Table.2 Required heads, nodal demand, diameter choice list, Costs and binary codes:

Pierre[1972] that Newton-Raphson converses very fast when initial guess of the unknown variables namely pies metric heads are determined by liberatization of the node equations assuming that the velocities in the network are 1 m/s.

GA Optimization:

Considering the fact that there are 21 potentially duplicated pipes discrete space of possible solutions is 21-dimensional. Diameter from the choice list is coded with 4 bits (Table) hence the coded strings (chromosomes) representing the final pipe network designs are made of 84 bits. The complex 21- dimensional space hides 2^{84} possible solution of the problem.

GA runs were allowed 50000 evaluations, which is a very small portion of solution space.Population is made of N=50 chromosomes and the probability of crossover is Pc=0.01 and it means that this operator alters each chromosome for the new generation.

The pressure constraint penalty multiplier Cp is the cost of one-meter pies metric head deficit. The value must be selected carefully to provide smooth transience from feasible to infeasible designs. The value Cp=20mil. $/m seems to meet that condition GA was run 5 times with different seed values for random number generator. The least cost design for each GA run and the necessary number for reaching it are shown in Table3.

Seed	Least cost Design (mil. $)	Number of Evaluations
1000	39.54	4800
2000	38.65	24550
3000	38.88	11800
4000	38.65	5650
5000	38.80	9550

Table3. Result of GA runs.

Twice GA has reached the best solution so far is 38.65 mil. $ Coincides with the solution obtained by Murphy et. al. [1993] who have improved GA for solving the problem. Number of evaluations for improver GA to converge was in the range of 100-150 which is much higher rate than for GA formulation presented in this paper Table.3.Results of GA design at38.65mil$ are presented in Table.4 and 5. Achieved solution suggest duplications of tunne7,16,17,18,19 and 21.Clear indication that proposed solutions is near to global optimum, is that differences is required and calculated pies metric heads in critical heads in critical nodes16, 17 and are very close to zero.

GA runs were allowed 50000 evaluations, which is only a small portion of the solution space. Population is made of N=50 chromosomes and the

Pipe	Diam. (mm)	Diam# (mm)	Cost ($/m)	Length (m)	Q (m^3/s)	Q# (m^3/s)
1	4572	0	0	3530	23.023	0
2	4572	0	0	6035	22.402	0
3	4572	0	0	2225	19.29	0
4	4572	0	0	2530	17.293	0
5	4572	0	0	2621	14.795	0
6	4572	0	0	3822	12.289	0
7	3353	3658	1713	2976	4.343	5.459
8	3353	0	0	3810	7.301	0
9	4572	0	0	2026	1.657	0
10	3962	0	0	3414	3.975	0
11	3962	0	0	4820	13.609	0
12	3353	0	0	3710	20.537	0
13	3657	0	0	7246	26.873	0
14	3353	0	0	6431	29.489	0
15	1829	0	0	4724	32.106	0
16	1829	2438	1037	8047	0.52	1.108
17	1524	2438	1037	9510	2.119	4.813
18	1524	2134	876	7318	0.968	2.347
19	1524	1829	725	4389	1.926	3.112
20	1524	0	0	11704	0.224	0
21	1829	1829	725	8047	5.293	3.293

Table.4 Result of GA design-38.65 mil. $ (# Relates to diameter and discharge of duplicated pipes)

probability of crossover is Pc= o.8. Probability of bit wise mutation was Pm=0.01.The adjancey mutation was implemented with highest rate Pa=1.0 and it means that this operator alters each chromosome for the new generation. The pressure constraints penalty multiplier Cp is the cost of one-meter pies metric head deficit. The value must be selected carefully to provide a smooth transition from feasible to no feasible designs. The value Cp=20mil$/m seems to meet that condition. GA was run 5 times with different seed values for random number generator. The least cost design for each GA run and necessary number of evaluations for reaching it are shown in Table 3.

Twice GA has reached the best so far solution of 38.6 mil. $ Result 38.8 mil$ coincides with solution obtained by Murphy et. Al.[1993] that have used improved GA for solving the problem. Number of evaluations for improved GA to converge was in the range100-150, which is much higher rate than for the GA formulation presented in this paper Table.3 Results of GA design at 38.65 mil. $ Are presented in Table4 &5. Achieved solution suggests duplications of tunnels7,16,17,18,19and 21.Clear indication that proposed solution is near the global optimum, is that differences in required and calculated piezometric heads in critical nodes 16,17and 19 are very close to zero.

Conclusion

Application of GA in mathematical programming problems and pipe network optimization presented in this paper shows that the concept is simple and results are excellent. The only drawback of GA is that they do not guarantee the optimum solution. Thus, many runs be made and the best result utilized.

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GIS Supported Water Balance Modeling: A Case Study

Dr.-Ing Abdulkarim Hussen AAU

Abstract

The presented paper describes an application of GIS for hydrologic modeling of catchment water balance. The model is a GIS-based grid-cell model. It reads and gives output in IDRISI – GIS format.

The catchment is modeled as a system of stream reaches and interconnected overland flow units (IOFU). These are grid cells that have one common outlet to a stream reach. This way it is possible to model any part of a catchment by specifying the location of the gauging station that is going to be used for calibration. With grid cells sub-divided into 3 to 4 conceptual stores, the entire catchment is then represented by system of stores between which flux of moisture occurs. These stores include the interception stores of the vegetation canopy, the overland flow store, and the soil stores. Flux of moisture could be either throughfall below a vegetation, surface runoff, vertical, lateral matrix flow or deep percolation. Hydrologic processes have been modeled using the conceptual approach where the magnitude of any process at any time depends up on store contents. Thus, all the stores of a single IOFU make up a system of simultaneous ordinary differential equations. These Differential Equations are then solved for all rainfall events during the simulation period.

The model has been tested on a catchment in Ethiopia. The catchment is one of the six nation-wide established sites under the Soil Conservation Research Project. It has been established for the purpose of studying different erosion protection measures under the local conditions.

The paper discusses the opportunities offered by GIS for distributed modeling of catchment hydrology. However, the science of modeling is confronted with new challenges, particularly with regard to model calibration and verification. The paper finally points out some of these challenges and recommends that more work is needed in the future.

1 Introduction

The task of determining river flows based on rainfall, evaporation and other watershed variables, occupies a central place in the technology of applied hydrology. The need arises not only in flood forecasting exercises but also in problems associated with the prediction of effects on stream flow of proposed works, or land use management practices. The problem has been studied from quite different angles in classical hydrology. With the advent of modern computational facilities, however, models have become common tools for solving such problems. The past three decades have witnessed a rapid growth in models. The models exhibit varying degrees of complexity depending upon factors such as intended purpose of model, data need, etc. The need to address the spatial variability of watershed characteristics has led to the development of distributed models. The development of distributed models has been facilitated by the introduction of Geographic Information System, which greatly enhanced the acquisition and management of geographically referenced data.

The present paper is primarily concerned with presenting an example of the new opportunities (and also challenges) offered by recent developments in the acquisition, and management of geographically referenced data in hydrologic modeling of watersheds. A case is presented where a GIS-based model is developed and tested in a small experimental catchment in Ethiopia.

The test catchment, known as the Auguchew catchment, lies in the Eastern Highlands, some 20 km east of Asebe Tefferi in a locality known as Hunde Lafto. This catchment is one of the six that have been established by the Soil Conservation Research Project in Ethiopia. It is currently operated by the Oromiya Regional State. It is 2.4 sq. Km. in area and has a good climatic and other relevant database.

2.The Modeling approach

2.1General

The model has two basic components, the catchment geometry module and the hydrologic process functions, which simulate components of the hydrologic cycle on a small watershed level. The catchment geometry module makes use of extensive use of GIS to extract the drainage network and other features that greatly facilitate the simulation of the catchment hydrologic processes. Both components of the model are described in the subsequent sections.

2.2 Watershed Representation in the Model

The river catchment, which is the hydrological unit under consideration, always exhibits wide variations within itself. Broadly speaking it contains soils with different hydrological properties, land use patterns that vary spatially and temporally, a unique topography and geology, and a drainage network that is highly dynamic in its morphology. All these influence the hydrology of the catchment to a greater degree.

The partition of the rainfall received in the catchment into infiltration excess and soil moisture largely depends upon soil type, land use type and to a lesser extent on the ground slope. The movement of soil moisture laterally towards the stream network or deep into the ground water reserve depends upon the stratification of the soil formation, the underlying geology and to some extent upon the slope of the ground surface. The excess rainfall sooner or later flows into well-defined channels and then to the catchment

outlet. The velocity of flow and hence the travel time thereby also the shape of the hydrograph at the outlet are products of more or less all the above mentioned catchment properties.

In the past catchment hydrology has been modeled with the catchment largely treated as a lumped unit. Hence, in such models, the spatial variability of hydrologic processes can not be reproduced. It is clear that in such models because of the lumping there is less power of prediction. Furthermore, they are of little use for studying, for example, influence of different land use management practices on the, say, stream flow from the catchment, etc.

With the advent of the modern computational facilities there has come with it the power of handling spatial data efficiently. Geographic Information System (GIS) - software are becoming indispensable in the hydrological analysis and synthesis. This has paved the way for distributed hydrological models, which recognize the spatial variation of catchment data. With such models the spatial variability, of say for example soil types in the catchment, could be represented by spatially distributed parameters.

In the present model, the catchment topography is represented by the digital elevation model (DEM) where the entire area is divided into equally sized square cells. These grid cells are also known as raster elements. Both terms shall be used here. The DEM has been established from the catchment topographic (contour) map. These raster elements are then considered as the smallest homogeneous unit of the catchment with regard to slope, land use and soil type. Likewise the soil and land use/cover maps are digitized to make distributed inputs of soil and vegetal cover.

With the help of a pre-processor computer program the catchment DEM is analyzed and flow direction is determined in each grid cell. The program uses the R8 algorithm, Martz [1988], and a single flow direction is assumed. In this program the overland flow is assumed to follow the ground surface slope, whose direction is automatically computed from the DEM.

The outcome of this analysis makes the basis for further classification of the raster elements that make up the catchment. Each raster element then has a follower element into which it drains, in the present case towards which its slope is the steepest, and the number of all raster elements that drain towards it i.e. its sub-catchment area.

The raster elements are then classified, based on some criteria, into two - those that make up stream segments and those that are purely overland-flow elements. Here it is very important to discuss the implication of this classification. Overland flow may proceed as sheet flow or as rill flow, Anderson [1990]. Hence if a grid cell is classified as an overland flow element then the infiltration excess leaves the element in the form of either sheet or rill flow. If on the other hand a raster element is classified as a stream segment then it means that this element contains a channel reach whose dimensions depend upon several factors among which soil type, slope and magnitude of flow rate are major ones.

Whether a cell is to be treated as an overland flow element or not is not of purely academic interest. The two flow conditions are quite different. Channel flow occurs in stream segments and the hydraulics of overland flow and channel flow is basically different. The basic difference stems from the difference in the geometry of section that accommodates the flow. Overland flow is generally associated with little detention storage, which is not the case for channel flow.

One important item in this classification is the criterion used. If the sectional geometry of flow is to be used as the basis for classification then amount of flow that a raster element receives is one of the most important factors to be considered. If all other factors remain same then the total area that drains into the raster element in question could be used as a criterion. However, other factors also come into play such as the vegetation, slope and type of soil of the area draining into the raster element. For example, for two different raster elements with same number of elements draining into them the one with generally steeper drainage area receives quicker concentration of flow hence greater peak flow than the other, all other factors remaining same for both elements.

In the present version of the model, magnitude of the drainage area is used as a sole criterion for classifying elements into overland flow and channel segments. It shall be refined in the future through research in this direction. However, for the present work a comparison is made with the drainage structure independently compiled from the supplied topographic map and the two conform quite well. Figure 2.1 shows both drainage networks. In this figure the continuous tree-like network corresponds to the drainage structure on the 1:10 000-scale topographic map whereas all other filled cells make the drainage network identified based on the criterion for stream reaches. In the present case a drainage area of 25 cells or more is used to define stream segments i.e. if a cell has a sub-catchment area of 25 or more cells then it is classified as stream element in contrast to other overland-flow elements.

Fig 2.1 Drainage networks, from topographic maps and those identified in the analysis of the DEM

It is important to note that the threshold number of cells used for delineation of channel segments affects mostly the choice of the first cell at which the channel network is assumed to start. Hence, for greater threshold value the channel network obtained becomes smaller and shrinks in the downstream direction, while the reverse is true as the threshold value decreases.

2.3 Interconnected Overland Flow Units

In simulating the hydrologic water balance of a watershed with raster data one of the advantages gained is the degree of fineness at which hydrologic component processes such as infiltration and overland flow are modeled.

Taking overland flow for example, for all raster elements, except those at the drainage boundary, each element receives flow from its upstream neighbor. The flow could be in the form of overland flow or channel flow, in addition to the flow generated on the element itself. Hence for routing both overland and channel flows the hydraulic interconnection of cells has to be considered. This calls for the identification of path followed by the water in flowing from the remotest cells to the catchment outlet. For this the output of the pre-processor program has been analyzed and further features of the drainage network extracted as outlined below.

After classification of cells into overland flow and channel elements has been done then the elements that drain into a stream segment are grouped in turn into several smaller groups, called interconnected overland flow units, in short IOFU. Each IOFU is then made up of all overland flow elements that have one common outflow point into a stream reach. The concept is illustrated as in figure 2.2 and figure 2.3.

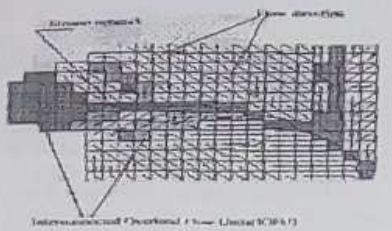

Figure 2.2 A section of the catchment showing the relationship between IOFUs and channel network

In effect, an IOFU can be taken as a patch of land (hillslope) that drains into the channel network through its most downstream element. This way the heterogeneity of the catchment in terms of soil type, land use/cover, topography, etc is addressed while the hydraulic connectivity is maintained.

2.4 Hydrologic Process Functions

As mentioned earlier the fundamental building blocks of the watershed water balance model are the component models that are used to simulate the hydrologic processes. In the simulation of water balance of the catchment, the relevant hydrologic processes to be considered include: rainfall space-time variability, evapotranspiration, interception, infiltration including deep percolation, soil moisture storage, overland flow, and channel flow.

These are components of the hydrologic cycle which describe the process of distribution, movement and storage of moisture in the catchment. The detail at which these processes are represented in catchment models depends on several factors, among which intended purpose of model, availability of data for calibration and later application of model, means of computation, etc., are major ones.

Catchment properties such as soil type, land use/cover, etc., greatly influence the hydrologic processes mentioned above. For instance, evapotranspiration is a function of the type and stage of development of the vegetation cover, apart from the climatic variables. Similarly infiltration depends on soil formation properties, vegetation type, initial moisture content, etc. Hence, spatial heterogeneity of the catchment in terms of its physiography means heterogeneity of parameters describing the process models.

To handle such heterogeneity in the present model process functions are allowed to take parameters that depend on the catchment properties at the grid-cell level. This does not mean, however, that the number of parameters to be used in the model is same as (or greater than) the number of grid cells used to represent the catchment area.

For instance, the infiltration function used has two parameters, namely the maximum initial infiltration rate and the final constant rate. Both are mainly functions of the soil type and to some extent the land use/cover type.

Figure 2.3 an example of IOFUs and the relation with channel elements

Hence, once these parameters are established for the different combinations of soil type and land use/cover, the parameters need not be redefined for each grid cell. It is important to note, though, that this is an area of extensive research needs and more and more refinement of parameter values is expected in the future.

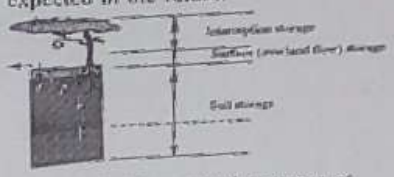

Figure 2.4 Conceptual storages at the grid-cell level

At the grid-cell level the model recognizes the system at hand as a series of interacting conceptual storages. These storages retain some moisture but after a certain threshold storage level is reached they also release part of their content into the next storage (hydraulically speaking) in line. The number of storages available for each grid cell is at the moment three, namely the interception storage, the overland flow (surface) storage, and the soil storage, figure 2.4. Thus the process functions operate on these storages. Continuity equation is applied for each storage to update the store contents. These, in turn, are used to compute values of the different process function, such as interception, infiltration, etc.

A summary of the main processes and the component models used are presented in Table 2.1. It is not possible give a detailed description of each and the reader is advised to look for details in the cited references.

Other processes such as deep percolation and lateral flux of moisture through the soil matrix have been approximated using the method by Bear [1972]. Because the emphasis has been on surface runoff and moreover the catchment has insignificant ground water flow the same has not been considered. It shall be included in the future versions of the model.

2.4.1 Channel Routing

Channels join each other and form the drainage network, a tree -shaped structure that converges at the catch-

No.	Process	Governing eqn.	References
1	Interception	$I = \frac{1}{k}(kC_{max} - E_o)(1 - e^{-k\Delta t}) + C_o(1 - e^{-R\Delta t})$ where C_{max} is the storage capacity of the vegetation canopy, K is the parameter of the model, E_o is the storage value at the beginning of the time interval, Δt.	Ostrowski (1996)
2	Infiltration	$f = (f_o - f_c)\left(\frac{1 - S_{mi}/S_{mx}}{1 - S_{mo}/S_{mx}}\right)^n + f_c$ where f_o is the initial maximum infiltration rate, f_c is the final constant infiltration rate, S_m is soil moisture, and the subscript i denotes the time, o denotes initial condition and x refers to the maximum soil storage capacity	Holtan (1961
3	Overland flow	$\frac{dh}{dt} = P + \frac{Q_{in}}{A} - f - \frac{\sqrt{S}\,B}{nB}h^{5/3}$ where P is precipitation, f is infiltration, A and B refer to area and width of the grid-cell, S is slope of the cell, n is Manning's roughness coefficient, h is the depth of overland flow, Q_{in} refers to the flow coming from a neighbouring cell	Lempert (1994)
4	Evapo-transpiration	$E_{act} = E_{pot} * f(\text{soil moisture})$	Doorenbos and Pruitt (1977), Maidment (1992)

Table 2.1: Main Processes and Models

ment outlet. In flowing through this system of watercourses the surface run-off hydrograph undergoes some modifications in its shape. Generally the peak gets reduced and the time base elongated. The computation of these changes to the inflow hydrograph is the subject of channel routing methods.

There have been developed in the past different routing methods that show varying degrees of complexity and data need. They generally fall into two groups. These are the hydrologic, or lumped, routing methods, where the change in the hydrograph along a channel reach is computed without considering what happens to it at intermediate points, and the hydraulic, or the distributed routing methods, where outflow hydrographs are computed at a mesh of points along the channel. Distributed models apply the physics of the flow more accurately than their lumped counterparts. However, they need detailed information that is not to be found especially for rural catchments. The treatment of such methods is beyond the scope of the present work.

An excellent example of hydrologic routing methods is the Muskingum method developed by McCarthy [1938]. The Muskingum method has been extended by Cunge [1969] and thereby enhanced the application of the method materially. This modified Muskingum method (known as the Muskingum-Cunge method), falls in the category of simplified distributed routing model. It is most effectively used as a distributed flow routing technique where the total channel reach is subdivided into smaller ones with length Dx and the same has been used in the present model. Details can be found in the above-cited reference.

2.5 The solution scheme.

As mentioned above the catchment is modeled as a system of interacting storages. The continuity equation is now applied to each of the stores with the inflow and outflow rates computed using the process functions discussed above. This results in ordinary non-linear differential equations that could be solved using any of the available numerical methods. The procedure is described using a section from the catchment as shown in figure 2.5.

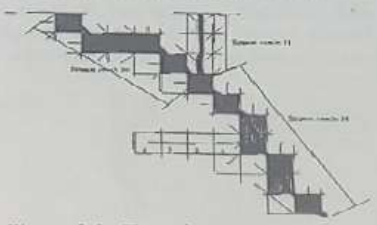

Figure 2.5: The solution scheme: definition sketch

In the figure are shown segments of three stream reaches, which are labeled 30, 31 and 38. In addition an IOFU is shown which has four elements. The element that drains directly into the stream reach is labeled 1. For simplicity of discussion it shall be assumed that each element has only one soil store in addition to the surface store.

Writing the governing equations for each store,

For the surface store

$$\frac{dh}{dt} = P + \frac{Q_{in}}{A} - f - \frac{\sqrt{S}\,B}{nB}h^{5/3} \qquad (2.1)$$

And for the soil store

$$\frac{dS_m}{dt} = f + I - E_{act} - C \qquad (2.2)$$

Where f is the infiltration that comes from the surface store, I the interflow coming from upstream elements, E_{act} the actual evapotranspiration and C the deep percolation.

In the present example the system has 8 stores, two for each of the four elements. Thus, the problem reduces to a system of simultaneous differential equations, which can be summarized in vector form as given below:

$$\begin{bmatrix} dS_1/dt \\ dS_2/dt \\ \cdot \\ \cdot \\ dS_8/dt \end{bmatrix} = \begin{bmatrix} f_1(t, S_1, S_2, \cdots, S_8) \\ f_2(t, S_1, S_2, \cdots, S_8) \\ \cdot \\ \cdot \\ f_8(t, S_1, S_2, \cdots, S_8) \end{bmatrix} \qquad (2.3)$$

The solution to the above equation can only be sought using numerical methods. The analytical integration of the non-linear process functions is not possible. The above equation is solved at each time step and the store contents are obtained, which are then used to compute values of process functions. For instance, knowing the value of the overland flow depth for an element the outflow can be computed which then becomes the surface inflow into the following element.

The routine used here for solving the set differential equations is written by Shampine and Watts [1976]. The routine is based on the fifth-order Runge-Kutta-Fehlberg method [1970] with adaptive step-size control. According this method, the solution is computed using two fifth and six order formulae. The difference of the two gives an idea on the truncation error

introduced by using the lower-order method. The truncation error so estimated is then compared with the given error tolerances to adjust the step-size of the independent variable, in our case the time t.

3. Results

As discussed earlier the model has been tested on a small experimental catchment in the Wabi-Shebele river basin. In this section some model output will be presented. The model output includes variation of soil moisture with time and streamflow hydrographs. The results shown are results of both the calibration and verification stages. Due to lack of data, however, the computed soil moisture values are not checked.

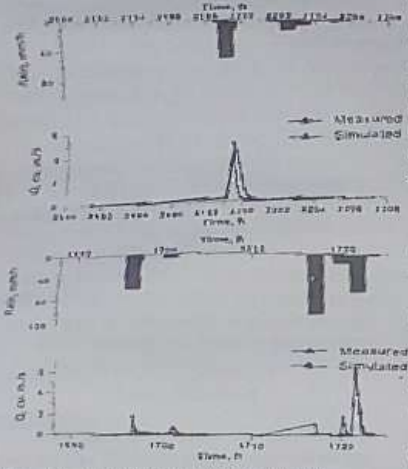

Fig 3.1. Simulated and measured runoff hydrographs (calibration)

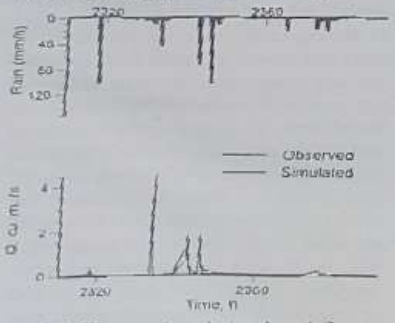

Fig 3.2 Observed and simulated flows – event 1, date April 8 (verification)

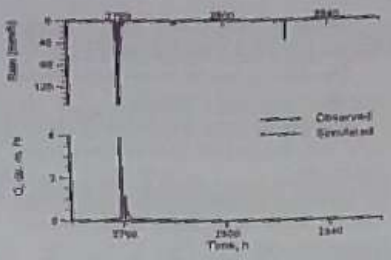

Fig 3.3 : Observed and simulated flows, event 2, date : April 25 (verification)

4. Discussion and recommendation

In this paper an example is presented on the application of GIS in hydrologic modeling of water balance at the catchment level. The model developed is a raster-based model, which accepts distributed inputs of catchment variables, such as topography, land use/cover, soil type, etc. It has been attempted to illustrate with the model the advantages offered by the use of GIS in such exercise.

The advantages

In summary GIS has facilitated hydrologic modeling in the following ways:

a) Spatial heterogeneity of the catchment is better addressed,

b) As a result of (a), hydrologic processes are now easily incorporated in catchment models in a more physically convincing way,

c) Use of Digital Elevation Model (DEM) enables the automatic delineation of catchment boundary and identification of the drainage network

d) Computation schemes in the models can now easily follow the path followed by the flowing water without requiring additional interference from the user during model run sessions.

e) Spatial data acquisition systems, such as satellite imagery, has made it possible to compile data on catchments that greatly enhance our understanding of hydrologic processes.

f) In general, GIS has facilitated the distributed modeling of watershed hydrology.

The new challenges

The use of GIS in hydrologic modeling has, on the other hand, posed new challenges to the science of modeling. This is associated with distributed modeling of catchment hydrologic processes, which is highly data-intensive. The parameters of component models should be estimated for different combinations of influencing factors. For instance, the storage capacity of the vegetation canopy is a function of vegetation type, stage of growth, degree of coverage, etc. Hence, to make accurate estimation of the model parameter, the relationship of this with the variables used for describing the vegetation cover has to be established, which needs more research.

Distributed modeling of watershed hydrology has a distributed output. Models compute soil moisture changes in space and time, runoff hydrographs can be produced for any desired point in the catchment, evaporation can be estimated for any patch of land, etc. In this context a fundamental question arises, how would then the performance of the model be tested?. Associated with it comes the question of the database to be used for model performance tests. In most of the watersheds such detailed data as would be required to test such distributed models is not available. Hence, the need is now greater more than ever for the collection of more data on components of hydrologic cycle.

It has been pointed earlier that distributed modeling is data intensive. In addition, distributed models require more time to run. This increases as the grid-cell size decreases. Hence, to model river basins that are on the order of hundred thousand kilometers one requires hours of computer time. Therefore, more powerful computers and computation algorithms are required to make such models practical.

In summary, GIS has opened new opportunities for model developers and users. At the same time the science of modeling is facing new challenges. The search for a solution to the challenges will make the predictive capacity of the models increase and together our understanding of the hydrologic cycle will improve. Hence, the need for more research can not be over emphasized.

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Surface Water Harvesting and Ground Water Recharge with Implications to Conjunctive Water Resource Managment in Arid to Semi-Arid Enviroments

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Abstract

To assess the surface water-groundwater relationships, and to determine the possibility of having an integrated method of surface and groundwater resource development, a study was conducted in the northern Ethiopia. About 40 micro-dam sites with existing springs and water wells for water supply were selected for this study. In this study, the groundwater resource potential of the aquifers before and after the construction of surface reservoirs is determined, and the groundwater quality before and after the construction of the structures is analyzed. This study shows that water leakage from surface reservoirs has recharged the groundwater systems, and this has increased the groundwater yield and reduced the groundwater depletion.

Most of the aquifers, which were characterized by poor quality water for drinking (as a result of high Total Dissolved Solids) are found to improve their quality after the construction of the surface water reservoirs, which could be associated to groundwater replenishment. Since most of the aquifers in the northern Ethiopia are characterized by shallow types, it is found feasible to apply the conjunctive (integrated) approach of surface and groundwater resource development. The integrated method of water resource development will help not only for optimum utilization of the water resource, but also for proper management and planning of the water resource.

The concept of the integrated (conjunctive) use of surface and groundwater is predicted on surface reservoirs impounding stream flow, which is then transferred at an optimum rate to groundwater storage. Surface storage in reservoirs behind dams supplies most annual water requirements, while the groundwater storage can be retained primarily for cyclic storage to cover years of subnormal precipitation. Countries in the arid to semi-arid environments are advised to consolidate responsibilities for integrating surface water and groundwater and assign to the same functional units in the planning, operations and services, and regulatory areas with equal attention to this principle at all levels of government.

KEY WORDS: Water harvesting, Groundwater recharge, Conjunctive water management, Mekelle.

Introduction

The northern part of Ethiopia is one of the drought prone regions in the country. At present the supply of drinking water for the major towns and for rural areas in the Mekelle area is from wells and springs. The rapid growth of population in both the towns and rural areas has tremendously raised the water demand of the area. However, the existing water supply is inadequate and insufficient to meet and fulfill this dynamic demand for water. Moreover, the numbers of small, medium, and large-scale industries, which require large amounts of water supply have increased in the Mekelle area. To satisfy such water demands, proper development and management of the water resource has become increasingly important.

This study was initiated to find alternative means of water resource management related to the conjunctive use of water resources (integrated method of surface and groundwater resource) in the arid to semi-arid environments of Ethiopia taking a model site of the Mekelle area. The Mekelle area is selected for this study because of the following reasons:

1.The area was studied for its groundwater resource potential by the Ethiopian Institute of Geological Surveys (Kifle et.al. 1995). This study included assessment and evaluation of springs, deep boreholes and hand-dug wells. The quality of water from the springs, deep boreholes and shallow wells was determined and analyzed for its suitability for various purposes.

2. Different types of surface water harvesting structures, such as micro-dams, diversions, and other soil and water conservation activities have been done in the study area, by different governmental and non-governmental organizations, in the last six years.

3. In addition to the previously existing data on water wells and springs, new water wells and springs have been developing in the last six years, in the Mekelle area.

The main objective of this study is to assess the effect of surface water harvesting on groundwater recharge, and to evaluate the possibility of using an integrated method of surface and groundwater resource management in the Mekelle area.

Study Area

Location. The study area is located between 13°00'N and 14°00'N latitudes, and 39°00'E and 40°00'E longitudes. It

includes the highlands of Mekelle and part of the low lands of Afar.

Climate and hydrology. The fact that the study area includes both the highlands of Mekelle and part of the lowlands of the Afar area results in high range of climatic differences in the study area. The moisture condition varies from semi-arid in the highlands of Mekelle to arid in the lowlands of Afar. The temperature also ranges from relatively cold in the highlands to hot conditions in the Aba'ala plain (Afar). According to the hydrometeorological data of the study area (Ethiopian Hydrometeological data of the years 1972-1999), the study area receives a rainfall ranging from 500 to 800 mm/year. The average annual temperature of the area is found to vary from 10°C to 20°C. The rainfall intensity in the study is also found to vary from medium to high intensity (20 to 60mm/day), leading to high runoff volume. Moreover, the evapotranspiration potential of the study area varies, with altitude and location, from 800mm/year in the Mekelle area to 1500mm/year in the lowlands of Afar.

Geomorphology and topography: The average elevation of the Mekelle area is about 2200 m above sea level with a range of 2000 - 2500m. The eastern escarpment of the rift valley is characterized by rolling hills and mountains (with elevation range of 1400 - 2000 m above seal level) and with steep slopes adjoining to the plains of the Aba'ala area.

General geology of the study area. Different types of rocks and soils with variable characteristics represent the study area. The following major soil and rock types (from the oldest to the youngest), characterize the study area: Metamorphic rocks, Glacial Tillite, Adigrat Sandstone, Antalo Limestone, Agula Shale, Ambaradom Sandstone, Intrusive rocks, Trap volcanics, and Alluvial soils.

The Metamorphic rocks mapped in the study area include slates and metavolcanics. The slates are characterized by green-gray to black slates and phyllites, partly graphitic and well laminated. The metavolcanics are represented by green to purple schist containing stringers of quartz and calcite. The Glacial Tillites are characterized by two major units: the lower sandstone unit is grey to black, poorly sorted pebbles and boulders (up to 6m diameter), sand-silt matrix, friable, and jointed (with joint opening up to 10 cm and with fracture continuity up to 30 meters). The upper unit is grey and purple silt, very well laminated and bedded with thin beds of and interbedded with thin beds of limestone and with drop stones.

The Adigrat Sandstone is represented by medium to coarse grained, red to brown sandstone with some shale and laterite bands. It is friable in places where it is iron cemented but massive in areas where it is cemented with silica. The Antalo Limestones are represented by yellow to white fossiliferous limestones and marls. The lower part is sandy, hard limestones while the upper part have large proportions of shales and marls. These rocks show karstification and travertine deposits with noticeable cavities and small caves.

The Agula Shale is characterized by grey, green and black shale with marl and clay. It is interlaminated with finely crystalline black limestone containing disseminated pyrite. It has 10 to 20% limestone beds, with the rest either of the jointed hard or soft powdery shales. Some gypsum beds are also noticed. The Ambaradom Sandstone is characterized by two units. The lower unit is represented by its medium to coarse grained, red clay and silt interbedded with white to pink sandstone. The upper part contains tuffaceous mudstone. In most cases it is associated with sequence of clay beds.

The Intrusive rocks (Dolerites and Diorites) are composed of intermediate igneous rocks and are represented by high degree of fracturing at the surface. With depth these materials tend to reduce in their degree of fracturing and hence their permeability. The Trap volcanics are black olivine basalts with coarse intergranular texture. Numerous flows with well developed columnar jointing and in some places with interbedded lacustrine deposits of silicified limestone characterize these Trap volcanics. Alluvial soils in the study area are those soils that are transported by water. These are mostly found along river channels and flood plains. These soils are dominated by sand with minor components of gravel and silt.

Different types of geological structures characterize the study area, among which are faults, lineaments, joints and bedding planes. Except for the Agula shale, the different types of rocks in the study area have moderate to high degree of fracturing related to the geological structures.

Materials and Methods

Different types of water harvesting structures have been under construction in the Mekelle area, among which are 22 dams and 20 ponds. Moreover, terracing and other soil/water conservation activities have been done in the study area. To study the effect of surface water harvesting on groundwater recharge, different materials and study approaches were employed.

Materials. The materials and equipment used in this research include: Aerial photographs and Topographic maps at scales 1:50000, Satellite imagery, Tracing paper and millimeter paper, Stereoscope, Geological compass, Geological hammer, Global Positioning System, Dipper (for water level measurement), Electrical Conductivity Meter, pH meter, Atomic Absorption Spectrometry and Current meters.

Methods. The methods and study approaches employed in this study include: review of previous studies and literatures; assessing the hydrology and general climatic condition of the study area; conducting geological, geomorphological and hydrogeological field survey; evaluating the hydrogeological characteristics of the rocks/soils; evaluating the effect of surface water harvesting on groundwater recharge and on groundwater quality; evaluating the possibility of using an integrated method of surface and groundwater resource development; generalization of the study results to make them useful in other study areas with similar environments.

The hydrogeological condition of the Mekelle area was studied in the period, February to March 1994 (Kifle et

al. 1993). The static water level and quality of water from wells was determined and the discharge and quality of water from springs was evaluated. The hydrogeological condition of the Mekelle area was also assessed during this study.

Since the groundwater condition and spring discharge is time dependent, the present study period is selected to be done during the period January to April 2000, for comparing with the 1995 data. In the present study, 76 observation points are selected (42 surface water reservoirs, 17 water wells and 17 springs). The static water level in the wells and the discharge of springs was measured. A total number of 400 water samples were collected from water wells, springs, and surface water reservoirs for quality determination, with a minimum of three samples from each observation point.

The static water level of the wells after the construction of surface water harvesting structures was compared with the static water level of the wells before the construction of such surface water reservoirs. The discharge of springs after the construction of surface water harvesting structures was compared with the discharge of springs before the construction of the structures. Moreover, the present quality of water was analyzed and compared with the quality of water from springs and wells before the construction of surface water harvesting structures in the area.

Results

Aquifer Characteristics of the Rocks & Soils in the Study Area

Different types of rocks and soils with variable aquifer characteristics are identified in the study area. The aquifer characteristics of the rocks and soils depend on many factors, among which are rock/soil types, morphological expression of the rocks/soils, and geological structures in the area.

Metamorphic rocks. These rocks have variable aquifer characteristics depending on rock type and degree of fracturing. The slates have low degree of fracturing and are classified as rocks with poor aquifer characteristics. In rare cases the slates have moderate aquifer characteristics, as a result of weathering, at shallow depths (not exceeding 10 meters). The metavolcanics have relatively higher degree of fracturing when weathered (up to 50 meters deep) and are classified as rocks with moderate aquifer characteristics for groundwater development.

Glacial Tillite. The lower unit has moderate to high permeability and is categorized as a rock with good aquifer characteristics except for its limited thickness (maximum thickness mapped is 10m). The upper unit is represented by low porosity and low permeability. As a result, the upper unit is categorized as a rock with poor aquifer characteristics for groundwater development.

Adigrat Sandstone. These rocks are represented by high porosity and high permeability. The geomorphological expression of these rocks (ridge forming) dictates their suitability as recharge zones to the regional groundwater system. These rocks are categorized as poor aquifers for groundwater development.

Antalo Limestone. These rocks are hard limestone and shale intercalations. The hard limestones are mostly well jointed and are represented by high permeability but the shales have low porosity and permeability. The limestones have good aquifer characteristics but the shales have poor aquifer characteristics. As a unit, the Antalo Limestone is classified as a rock with moderate aquifer characteristics. In many places, cold springs emerge at the contact of the limestone beds with the intercalating shales and marls. A few of these springs have large discharges, up to 50 lit/sec in the wet seasons and no discharges in dry seasons.

Agula Shale. These rocks are represented by low porosity and low permeability, and are classified as rocks with poor aquifer characteristics. Due to the weathering of these rocks at shallow depth, they contain shallow groundwater providing mostly low yield. This formation is characterized by numbers of springs, which issue at the contact of overlying Antalo Limestone beds with Shales.

Ambaradom Sandstone. This unit is characterized by medium to high permeability. But due to its ridge forming morphological expression, it is classified as a unit with poor aquifer characteristics for groundwater development, but acting as a good recharge to the regional groundwater system in the area.

Intrusive rocks. These rocks have high degree of fracturing at shallow depths (maximum of 80 meters). With increase in depth, these materials tend to reduce in their degree of fracturing and hence their permeability. Because of their high permeability at shallow depth, these rocks are good aquifers for shallow groundwater development.

Trap volcanics. These rocks have medium to high permeability. Since these rocks are ridge forming, their morphological expression favours their suitability as recharge zones to the groundwater systems. These rocks are, therefore, represented by poor aquifers for groundwater development.

Alluvial soils. These soils have moderate to high permeability. The permeability and productivity varies from place to place depending on grain size, sorting and thickness. Except for their limited extent, the alluvial soils in the study area are categorized as good aquifers for shallow groundwater development. The alluvial soils along streams are some of the most common shallow groundwater aquifers, which can be tapped by larger diameter hand-dug wells.

Geological structures. Different types of geological structures characterize the study area, among which are faults, lineaments, joints and bedding planes. Except for the structures in the Agula shale, most of the large-scale geological structures in the study area have good aquifer characteristics for groundwater development.

Surface Water Harvesting & Ground Water Recharge to Water Wells

Different types of surface water harvesting structures (dams, ponds and diversions) have been under construction for the purpose of irrigation and water supply, in the last six years, in Mekelle area. Wells (deep and shallow types) were constructed before 1995 in different parts of the Mekelle area for water supply. Table 1 shows the static water level and quality of

groundwater before and after the constructions of surface water harvesting structures in certain localities within the study area.

Surface Water Harvesting & Ground Water Recharge to Springs

In the Mekelle area, many springs that issue at the contact between rocks/soils of high permeability contrast are very common. Table 2 shows the springs that are identified and the quality of spring water in the different localities of the study area.

Water Quality From Micro-Dams Versus Quality From Wells & Springs

The quality of water (physical, biological and chemical behavior) was determined by taking water samples from surface reservoirs, springs, and water wells. The pH values for the surface water, groundwater and spring water is measured to be in the range of 7.5 - 9.5. The results of the analysis are indicated in Table 3.

Source	Water Quality			
	Color	Turbidity	TDS (mg/lit)	Pathogenic organisms (coliform bacteria MPN/100ml)
Surface Water	Variable	Slightly to highly turbid	180 - 1000	Positive (3 counts) for coliform bacteria
Spring water	Clear	Clear	800-1250	Free
Groundwater	Clear	Clear	805 - 1450	Free

Table 3. Data showing the quality (physical, biological and chemical) of water sampled from surface reservoirs, springs, and wells (Kifle W., 2000).

Discussion

In this study, the effect of surface water harvesting on groundwater recharge is investigated and the possibility of applying an integrated method of surface and groundwater resource development in the Mekelle area is evaluated. Since the Mekelle area is within the arid to semi-arid environments, with poor groundwater resource potential, looking for options that optimize the utilizations of the available water resource becomes critically important.

Locality Name		Well Depth (m)	Before constructing surface water harvesting structures		After constructing surface water harvesting structures	
			Static Water Level (m)	Water Quality (TDS) (mg/lit)	Static Water Level (m)	Water Quality (TDS) (mg/lit)
Adi-gudom	Adi-gudom W1	30.3	43.3	1800	24.2	900
	Adi-gudom W2	45.9	Dry	-	27.3	1000
	Adi-gudom W3	60.3	30.3	1400	33.5	890
	Adi-gudom W4	33.2	48.8	1450	33.5	1000
	Adi-gudom W5	45.3	Dry	-	41.3	850
Agula	Agula W1	33	Dry	-	Dry	-
	Agula W2	63.5	33.4	1450	50	1050
	Agula W3	70.8	60.1	1200	Dry	-
Negash	Negash W1	67.6	33.5	850	Dry	-
	Negash W2	53.7	35.8	1005	43.4	1230
Feleg wuero	Feleg wuero W1	65.3	30.3	1230	35.8	980
	Feleg wuero W2	50.3	35.2	1420	32.3	1000
	Feleg wuero W3	70.1	55.3	1340	29.5	850
Aba'ala	Aba'ala W1	63.5	55.8	1450	40.8	970
	Aba'ala W2	45.8	40.5	1340	30.3	1150
	Aba'ala W3	60.4	53.3	1270	45.5	880
	Aba'ala W4	70	48.5	1100	40.3	805

Table 1. Data showing the static water level and quality of water from wells (before and after the construction of surface water harvesting structures)(Kifle et al, 1995; Kifle 2000.).

Locality Name		Before constructing surface water harvesting structures		After constructing surface water harvesting structures	
		Spring Discharge (lit/sec)	Water Quality (TDS) (mg/lit)	Spring Discharge (lit/sec)	Water quality (TDS) (mg/lit)
Adi-gudom	Adi-gudom S1	Dry	-	5	830
	Adi-gudom S2	Dry	-	7	1030
	Adi-gudom S3	Dry	-	10	800
	Adi-gudom S4	0.5	1000	13	960
	Adi-gudom S5	1	905	12	870
Agula	Agula S1	Dry	-	Dry	-
	Agula S3	0.3	980	Dry	-
	Agula S3	0.3	1130	Dry	
Negash	Negash S1	0.2	880	Dry	-
	Negash S2	Dry	-	Dry	-
Feleg wuero	Feleg wuero S1	Dry	-	15	960
	Feleg wuero S2	0.8	1230	10	1110
	Feleg wuero S3	0.5	1350	15	1005
Aba'ala	Aba'ala S1	Dry	1450	11	1250
	Aba'ala S2	5	1340	15	1210
	Aba'ala S3	Dry	-	10	800
	Aba'ala S4	2.5	1100	17	995

Table 2. Data showing the discharge and quality of spring water before and after the constriction of surface water harvesting structures (Kifle et al, 1995; Kifle W. 2000)

The aquifer characteristics of the rocks and soils in the study area are represented by shallow unconfined types, with thickness ranging from few meters to 80meters (average thickness not exceeding 50 meters). The shallow nature of the aquifers is related to the weathering of the rocks at shallow depths and/or to the presence of low permeability materials intercalating the more permeable rocks. The rocks with low permeability, like shales, are acting as aquicludes, retarding deep percolation of groundwater. Some of the rocks, represented by moderate to high degree of permeability, have poor aquifer characteristics because these rocks are acting as recharge zones to the regional groundwater systems.

Different types of surface water harvesting activities have been done in the last six years, among which are construction of dams, ponds, diversions, and soil/water conservation activities. Some of the constructed dams have been suffering from excessive seepage due to different reasons among which are lack of proper site investigations, lack of proper design and/or lack of proper construction.

The Adi-gudom area is underlain by rocks of the Agula shale and Antalo-limestone. In this locality, different surface water harvesting structures (ponds and small-scale dams) and other water conservation activities have been constructed and some of the constructed ponds and dams have been suffering from seepage. These have re-

sulted in the recharge of the groundwater systems, which is manifested by the raise in the static water level of the shallow wells and by an increase in the discharge of springs in the Adi-gudom locality (Tables 1 and 2).

The Agula area is underlain by Agula shale and Antalo-limestone. Except for very minor soil and water conservation activities, there was no major surface water harvesting activity in this locality. As indicated in Tables 1 and 2, there has been water depletion in the shallow groundwater systems. Moreover, the spring discharge is found to reduce. A similar case was observed in the Negash locality, where there was no major surface water harvesting activity. Because the Negash area has poor groundwater recharge to the wells and springs, the groundwater resource is found to deplete. Moreover, the recharge to springs is found to decrease in this locality.

The Feleg-Waero area is underlain by Agula shale and Antalo-Limestone. In the catchments of this locality, different types of surface water harvesting activities (including the construction of dams) have been done in the last years. As indicated in Tables 1and 2, the water level in the wells has raised and the discharge of springs increased, which is related to the recharge from surface water reservoirs.

The Aba'ala area is underlain by Agula shale, Antalo-Limestone and Alluvial soils. In the catchment areas of the Aba'ala locality, different surface water harvesting structures have been constructed. This has resulted to an increase in the recharge of the groundwater systems and to an increase in spring discharge.

The quality of water from wells and springs in the Mekelle area is found to have higher Total Dissolved Solids, free of pathogenic organisms and with clear colour when compared with the quality of surface water (from surface reservoirs). On the other hand, the quality of surface water is found to have relatively low Total Dissolved Solids, with some pathogenic organisms, and turbidity. In the localities where there has been intensive surface water harvesting activities, the value of the Total Dissolved Solids (TDS) in the groundwater and spring water is found to decrease after the construction of the surface reservoirs. The reduction in the value of TDS is related to the groundwater recharge and replenishment. In the localities where there has been limited or no surface water harvesting activities, the value of the Total Dissolved Solids (TDS) in the groundwater and spring water is found to increase. The reduction in the quality of groundwater in the areas where there has been poor groundwater recharge is related to groundwater depletion.

The application of the integrated method of surface and groundwater resource development is found to be very important for optimum utilization of the water resource. The surface water harvested is transferred to groundwater storage as the surface storage in reservoirs behind dams supplies most annual water requirements, while the groundwater storage can be retained primarily for cyclic storage to cover years of subnormal precipitation. During periods of precipitation, surface water could be utilized to the maximum extent possible and also recharged into the ground to augment groundwater storage and raise groundwater levels. Conversely, during drought periods limited surface water resources are supplemented by pumping groundwater, thereby lowering groundwater levels.

Aquifers can no longer be looked on as everlasting sources of abundant water of good quality. Aquifers run dry with increased use. Increases in urban wastes and expansion of industry and agriculture can lead to deterioration in the quality of groundwater. Sustainable and optimum water management requires an integrated approach to the management of both surface water and groundwater. Management plans would be greatly enhanced if they were based on detailed knowledge of the characteristics that make conjunctive use of surface water and groundwater efficient and effective.

Conclusion

From this study the following points are concluded:

1. Since the rocks and soils in the study area are characterized by shallow but unconfined aquifer types, the application of an integrated method of surface water and groundwater resource development and management is found to be feasible in the study area.

2. The surface water harvested in the different localities has recharged the groundwater systems. The groundwater recharge is found to increase the groundwater yield, decrease the groundwater depletion, and favour sustainable groundwater development.

3. The surface water harvested in the different localities within the study area has resulted to an increase in spring discharges, and favour sustainable spring development for different purposes (water supply, irrigation and industries).

4. In the localities where there has been intensive surface water harvesting activities, the quality of groundwater is found to improve after the construction of surface water reservoirs. The water quality improvement is associated with reduction in the Total Dissolved Solids due to the dilution of the dissolved solids in the groundwater systems. The soil/rock masses in which water migrates through are also acting as natural filters to the pathogenic organisms and fine materials that may be present associated with surface water.

5. In arid to semi-arid environments, the application and use of an integrated method of surface and groundwater development would greatly help in minimizing the ill effects of evaporation, as the dumping effect of the underground could be very high.

6. The application of the integrated (conjunctive) method of surface and groundwater development is found to be very useful for optimum utilization and sustainable management of the water resource in the study area, as there is sufficient surface water with suitable geological, geomorphological and hydrogeological conditions.

Recommendation

From this study, the following points are recommended:

1. Since the Mekelle area is found to be suitable for applying the integrated method of surface water and groundwater resource development, organizations that are involved in wa-

ter resource development (for water supply, irrigation and industries) are advised to use this conjunctive method of water resource development.

2. One of the problems associated with the use of surface water for drinking (especially for rural community) is contamination of surface water from surface contaminants. The use of surfa water for the rural community.

3. When applying the conjunctive use of water resource in any area, surface water is the main source of recharge to the groundwater systems. If the surface water in the area is polluted, it is highly possible for the groundwater systems to be polluted. It is highly advisable to assess the pollution potential and device a mechanism of reducing the pollution of surface water and groundwater resource.

4. In arid to semi-arid environments, the application of the integrated method of surface and groundwater resource management is important not only for optimum water utilization but also for sustainable management of the water resource of an area. The application of the conjunctive method of water resource management in areas with suitable hydrological, hydrogeological and environmental conditions is highly recommended in other parts of the country.

5. Countries in the arid to semi-arid environments are advised to consolidate responsibility for integrating surface water and groundwater development and assign to the same functional units in the planning, operations and regulatory areas with equal attention to this principle at all levels of government. This would greatly help for optimum utilization and sustainable management of the water resource, which helps for sound environmental planning and management.

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[2] The static water level is measured from the ground surface.

[3] Present water supply for Adi-gudom town.

[4] MPN is an abbreviation for Main Problem Number: it is a measure of the concentration in a water sample of 100ml.

[5] Water from surface reservoirs is observed to have variable color (from light gray to light green) and with some turbidity.

Reginal Flood Frequency Analysis: The Rift Valley Lakes Basin

Mesfin Berhanu ,Sileshi Bekele Arbaminch, AWTI

Abstract

Regional Flood Frequency Analysis uses data from a number of sites in a region to establish a regional growth curve. A region is a group of sites assumed to have the same frequency distribution at every site apart from a site-specific scaling factor called the index flood. The grouping can be based on either geographical, climatic or catchment characteristics of the sites. Statistical tests are then done to test the hypothesis of homogeneity. This study describes a regional frequency analysis done on the southern part of the Ethiopian Rift Valley Basin called the Rift Valley Lakes Basin (RVLB). The discordancy test done on the sites showed that the hypothesis of homogeneity couldn't be rejected. The homogeneity test based on X_{10} provided a satisfactory result. A GEV distribution with three parameters is proposed for the regional growth curve with parameter values: k = -0.223, a = 0.339 and u = 0.720. No significant improvement in the X_{10} estimate was found by dividing the region further in to Northern and Southern regions based on the slight variation in the rainfall pattern. However, it is observed that developing separate regional growth curve based on rainfall and physiographic pattern produces significantly differing regional growth curves.

Introduction

The Study Area

The study area is designated as the Southern part of the Ethiopian Rift Valley Region, which is known as the Rift Valley Lakes Basin (RVLB).

Objective

The objective of the study is to develop a regional curve that can be used to estimate flood quantiles, i.e. discharges associated with exceedance probabilities which can be used in the design of small to medium hydraulic structures such as dam spillways, bridges, culverts and other similar structures in the study basin. These flood quantiles are obtained from the frequency curve established for the river basin.

Method

Depending on the amount and type of data available, flood frequency analysis is usually done based on either:

- at - site data alone,
- at - site/regional data, or
- regional data only

At site frequency analysis is purely statistical. If the record length is longer, say more than 30 years, at site frequency analysis provides a curve that can give somewhat acceptable results. However, if the frequency curves were obtained from a record less than 25 years, it is recommended (NERC, 1975) that the extrapolation of the curve to only 2N years; here N is the length of record. Beyond this and up to 200 years or more, it recommends the use of regional frequency curve. It is therefore recommended that where regional data exist it is best to adopt a regional estimate than to use at site data alone, even if the assumption of regional homogeneity cannot be proved to be true. Use of at site data alone leads to a less reliable result.

Regional Flood Frequency Analysis

Regional flood frequency analysis uses data from several sites to estimate the frequency distribution of the observed data at each site to enable Q-T relationship to be obtained for ungauged site(s) or to improve the precision/accuracy of Q-T estimates at sites with short to medium record lengths. Regional frequency analysis is the hydrological term used to describe the activity devoted to establishing the frequency curve that describes the relationship between the magnitude of a hydrological event (e.g. flood peak) that exceeds a certain amount with a stated frequency or return period based on regional data. One such approach is the Index Flood Method.

The Index Flood Procedure

Under the assumption of regional homogeneity of distribution type the observed data at many sites in a region may be pooled to provide a more precise estimate of standardized quantile such as $X = Q_T / Q$ where is the at site mean annual maximum value of Q. For ungauged catchments, may be obtained from a relationship between and numerically expressible catchment characteristics such as area, channel slope, mean annual rainfall, and stream frequency among others. An estimate of obtained from catchment characteristics is not, however, as reliable as one obtained from at site data.

In this procedure, the frequency distribution of X is assumed to have the same form at every site apart from a site-specific scaling factor, the index flood (in this context). The parameters of the distribution of X are obtained from the combined regional

$$\hat{Q}_T = \overline{Q} \cdot X_T$$

data sets. The quantile Q_T is then estimated as:

The parameters of the X distribution method may be obtained by regional averaging of dimensionless probability weighted moments (PWMs). This method has been found to be easy to apply and is robust and efficient (Cunnane, 1989).

It is preferable that the flood series should be homogeneous, i.e. they should all either be instantaneous peak flows from a water level recorder, peak values from staff gauge readings, or maximum daily flows.

Data Availability

Data collected from 22 stations is used in the study. The record length varies between 7 and 27 years and other details given separately.

Study Background

No.	Sta. No.	Record	N	Mean	LCv	L-Skew	L-Kurtosis	Di
1	081003	1980-95	16	9.319	0.369	-0.071	0.114	1.177
2	081016	1970-76	7	35.849	0.389	0.003	-0.208	2.234
3	-	1970-76	7	91.257	0.458	-0.072	0.180	1.123
4	081011	1983-95	12	125.868	0.274	0.333	0.359	0.875
5	081019	1970-82	13	98.612	0.326	0.412	0.241	0.874
6	081017	1981-93	11	3.226	0.439	0.364	0.218	0.226
7	081008	1982-93	12	15.280	0.371	0.353	-0.041	1.960
8	081009	1983-93	9	20.880	0.690	0.521	0.216	2.548
9	081018	1985-96	12	13.451	0.166	0.012	0.368	1.272
10	-	1984-94	11	81.735	0.184	0.115	0.234	0.587
11	081021	1983-93	9	10.489	0.298	0.133	0.083	0.733
12	081010	1983-93	12	19.018	0.467	0.484	0.274	0.444
13	082032	1981-89	9	14.608	0.473	0.305	0.105	0.597
14	-	1971-87	12	144.73	0.195	0.302	-0.086	1.730
15	082008	1971-96	23	84.568	0.204	0.198	0.175	0.112
16	-	1983-92	10	103.373	0.236	0.299	0.089	0.558
17	082016	1976-98	22	31.003	0.259	0.011	0.165	0.785
18	08100107	1980-98	12	20.536	0.343	0.143	0.177	0.868
19	082034	1982-95	13	36.453	0.426	0.499	0.228	0.493
20	082019	1980-96	13	20.183	0.335	0.319	0.278	0.351
21	082017	1974-88	12	20.306	0.258	0.514	0.478	1.813
22	-	1980-93	14	16.810	0.431	0.693	0.433	1.246
				Average	0.328	0.282	0.185	1.060

Table 1. Summary of statistics for the stations used for RFFA in the study area

Admassu (1989) conducted a comprehensive flood frequency study for most of Ethiopian rivers, which includes Northern portion of the study area under the RVLB. He proposed a single regional frequency curve for the Northern and central RVLB. Obviously, this cannot be extended for the whole of RVLB due to the associated heterogeneity. As shown in Seleshi (2001), rivers included in Admassu's study of the RVLB belong to two different climatic and rainfall pattern and may not be incorporated as one region.

Another study made in relation to Gelana Irrigation project, by A. Gibb and partners in association with Atkins international, Gibb and Partners (1987), provides the study of flood and storms and regional growth curve for flood of rift valley and adjacent basins. It was based on data records of the whole of rift valley region and that of adjacent basins, and the study was based on GEV with probability weighted moments (PWM) method. In this study, the derived sub-regional and joint flood frequency curve does not identify homogeneous regions and such result could lead to inaccurate estimate due to large heterogeneity involved.

In this study, it is proposed to undertake a regional flood frequency analysis and develop a regional growth curve for the whole of RVLB. It is also intended to show if there could be any improvement in the estimation by dividing the region in to two sub-regions, instead of one region only, based on the rainfall pattern and rainfall-runoff responses.

Identification of Homogeneous Regions

Traditionally, the main criteria for grouping gauging site into groups with the intention of forming homogeneous regions for regional flood frequency analysis were:

1. Geographical – all gauging sites in a given geographical area were included in the proposed hydrological region

2. Climate – the country to be regionalized is divided into regions with differences in their climatic regions e.g. high rainfall and low rainfall regions

3. Size – the country to be regionalized has its gauging sites assigned to regions dependent on the catchment area measured to the gauging station e.g. a region containing sites whose catchment areas A_0, where A_0 = 10 km², 100km², or 1000 km² say, and another region containing sites whose area A_0

Discordancy Measure

Hosking and Wallis (1997) introduced the discordancy measure D to identify those sites that are grossly discordant with the group as a whole prior to performing RFFA. Discordancy is measured in terms of the L-moments of the data (Hosking and Wallis, 1997). The discordancy calculated for each site in the group tells whether a site belongs to the group or otherwise if there was no error in the data. Hosking and Wallis (1997) suggested critical values to test the null hypothesis of no discordancy. For number of sites N≥ 15 if a sites Di > 3 the sites data is considered to be discordant from the rest of the regional data at 10% level of significance. For $N < 15$, the values are smaller being approximately 2 at $N = 7$ and $N = 8$. For $N < 7$, the discordancy test is not likely to be useful.

The discordancy calculated for the 22 stations is given in the Table 1 below. None of the stations used in the study show a discordancy value greater than three. This preliminary analysis suggests that the hypothesis of homogeneity cannot be rejected at least at this stage.

Climate and Physiography

The other approach in this study is to subdivide the region into two homogeneous regions based on rainfall and physical characteristics.

Region A– regions of mainly unimodal rainfall and relatively flat areas

Region B – regions of bimodal rainfall and relatively steep slope associated to the rift valley escarpments of the Abaya Chamo region, excluding the upper part of Bilate River drinage.

Figure.1 shows plots of the L-Cv vs L-skewness and L-kurtosis vs L-skewness. The center of the cloud of points, marked by a plus, is the point whose coordinates are the group average values. If a single site does not appear to belong to the cloud of points, i.e. vary far from the center, on the L-moment

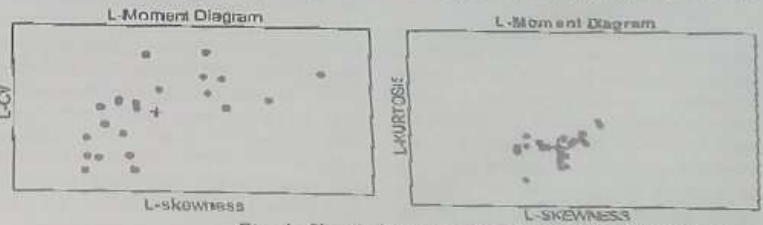

Fig. 1. Sketch for diagram of discordancy base on

L-moments can be used to determine whether it should be removed from the region.

Tests of Homogeniety of the Regions

$$X_T = Q_T / \mu$$

Homogeneity Tests

If a region is homogeneous in the flood hydrology sense we assume, in the index flood method that, the

has the same value at each site for

- $X_{10}^{(i)}$ (Dalrymple, 1960)
- $C_v^{(i)}$ (Wiltshire, 1986)
- L-Cv (recommended by Hosking and Wallis, 1993)

all T. That is the statistical distribution of Q_T/m is the same at all sites. The homogeneity of a region can be tested

$$S = \sum_{i=1}^{N} (X_{10}^{(i)} - X_{10}^{(R)})^2$$

on the basis of

The homogeneity test based on X_{10}, the homogeneity of the region is measures by

where $X^{(i)}_{10}$ is the estimate of X_{10} at each site in the region, and $X^{(R)}_{10}$ is the regional estimate. If S is small the region is homogeneous; otherwise it is not. "Small" has to be judged against the sampling distribution of $X^{(i)}_{10}$, obtained under the null hypothesis of homogeneity. This can usually be obtained by simulation methods.

The tests based on X_{10} or Cv tests only one aspect of the distribution of X for homogeneity. However, since homogeneity of X_{10} or Cv is a necessary condition for homogeneity of the X distribution in its entirety, rejection of the hypothesis of homogeneity X_{10} or Cv implies rejection of this hypothesis for the X distribution as a whole. Of course, on the other hand, acceptance of the homogeneity of X_{10} or Cv does not guarantee the homogeneity of X as a whole but this is usually assumed.

The discordancy measure D_i is based on L-moments (L-CV, L-skewness and L-kurtosis)

For the sites considered in this study, a homogeneity test based on X_{10} was undertaken and is displayed in Fig. 2.

Comparison of at-site and regional

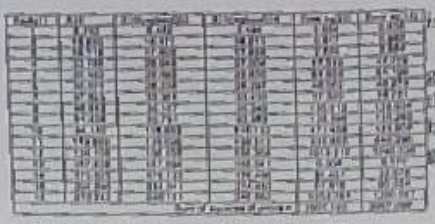

Table 2. Estimates of X_{10} using 22 stations and 16 stations

estimate of the 10 years return period flood shows that the region is reasonably homogeneous. The test also showed that dividing the region in to two sub-regions by their rainfall pattern does not show any improvement than considering all the 22 stations together.

Reginal Growth Curve

a) Grouping Entire RVLB as One Region

In this approach it is proposed to use the three-parameter GEV distribution for the region. This is done by regional averaging of dimensionless PWMs: M_{110}/M_{100}, M_{120}/M_{100}, ...as outlined by Wallis (1980). This method has been found to be easy to apply and

Standardized PWMs		GEV Parameters	
M_{100}	1.000	k	-0.223
M_{110}	0.651	a	0.339
M_{120}	0.501	u	0.709

Table 3. Standardized regional PWMs and GEV parameters

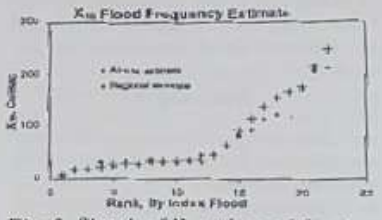

Fig. 2. Sketch of X_{10} values of the at-site and regional estimate (22 stations)

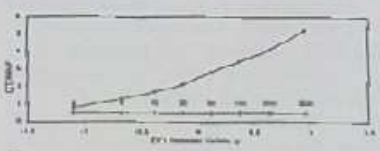

Figure 3. Regional Growth Curve, 22 stations

is robust and efficient.

For the sites considered Table 3 gives the standardized moments and the estimated parameters.

b) Subdividing the RVLB In to Regions A and B

Regions	a	k
A	0.765091	0.377136
B	0.696551	0.121412

Table 4: Regional parameters of GEV distributions

From the parameters of GEV distributions of the regional flood frequency curves the estimates of these parameters are given

The equation describing the distribution and utilizing parameters given in Table 3, results in:

For Region A:

$$X_T = 0.765091 - 7.1850\left\{1-\left(-\ln\left(1-\frac{1}{T}\right)\right)^{-0.377}\right\}$$

For Region B:

$$X_T = 0.69655 - 1.1732\left\{1-\left(-\ln\left(1-\frac{1}{T}\right)\right)^{-0.214}\right\}$$

Note that $F(x)=1-1/T$, where T is return period.

Observation of the shape parameters suggests that Region A can also be modeled using Gumbel Type I (EVI) distribution as an alternative. This is so because the value of k for region A is not significantly different from 0. The result of the computation provides a T year event, based on Gumbel Type I distribution for Region A as:

$$X_T = 0.774076 - 0.391413\left\{\ln\left[-\ln\left(1-\frac{1}{T}\right)\right]\right\}$$

The X_T values for different T were calculated using the above-derived equations and the results are provided in Table 5 .

The Q_T vs. Gumbel reduced variate for EVII distributions for both regions as well as EVI distribution for Region A are given in Figure 4.

The obtained results in above are differing from the results given in *Admasu (1989)*. The two regions are also providing significantly different results for estimation of flood at higher quantiles. On one hand, the reported result provided assessment of the region with more data, and on the other

Region, Distribution	Return Periods (Years)								
	2	5	10	25	50	100	200	500	1000
A_EVII	0.90281	1.36172	1.63337	1.96038	2.37451	2.69582	3.03547	3.49131	3.83661
A_EVI	0.91353	1.34317	1.6349	1.91085	2.30614	2.57464	2.84621	3.20611	3.47751
B_EVII	0.83047	1.39779	1.69643	2.19041	2.58017	3.40044	4.52938	5.96054	7.30712

Table 5: Regional Flood Frequency Growth Factor

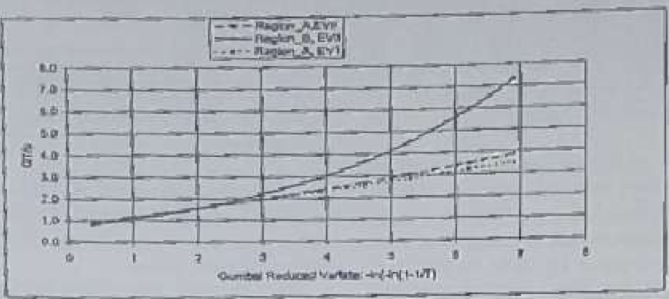

Figure -4: Regional Growth Curves of Northern and Central RVLB

gion with more data, and on the other hand the rationalization based on rainfall identified the differing regions of the RVLB independently, with differing flood frequency growth equations.

The higher difference observed in the higher quantile in the two regions, which provides higher estimates of flood for Region B is due to the fact that most of the rivers in Region B are located at the escarpments of the Rift Valley and where high rainfall and flood are expected, and hence high flood at higher quantiles. On the other hand, due to a relatively low rainfall and low flood magnitudes in upper rift valley lakes region (Zway-Langano-Awassa) areas and significant gauging stations are lying in this low land, low flood areas and the occurrence of large flood is quite seldom. In Region B, the rift Valley floor is also narrowing with significant elevation variation and slopes and hence high flood response and higher flood magnitudes are expected.

Conclusion

A regional flood frequency analysis for the RVLB is done. Regional growth curve for the region is developed for flood estimation to be used for small hydraulic structures. The proposed distribution is GEV with three parameters. When one can considers the discordancy measure alone as a criteria to identify homogenous regions, it is found that all the stations considered in this study can be taken as homogeneous region in spite of the difference in the rainfall pattern. An attempt to divide the region has shown almost no difference with that estimated from the 22 stations.

However, considering the rainfall pattern combined with difference in physiography, and grouping the RVLB in to two distinct regions, we obtain distinct flood growth curves, which provides varying flood magnitudes at large return periods.

Taking more data stations and covering larger area of the country, the regional frequency analysis can be done to a better result by considering a number of distributions combined with various parameter estimation procedures. For other regions too, this type of study has to be continued. So far, there is no reliable method developed to estimate flood frequency in the country.

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Determination of Rainfall Cyclicity over selected locations in Ethiopia

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Abstract

Rainfall is one of the climatic parameters that have great importance in rain-fed agriculture. However, it shows systematic and irregular variations over time and space. These variations play significant role in adapting farming systems, agricultural planning, crop selection, and thus productivity. The characterization of these systematic variations will contribute not only in long term agricultural planning but even in long range weather forecasts.

To characterize these variations and assess the cyclic pattern, the annual rainfall data for eight selected meteorological stations have been considered in this study. The main objective this paper is to assess whether there is cyclic trend on the annual rainfall distribution.

The result of the study is encouraging since there appears to be a cyclic tendency in the annual rainfall data. Hence, the results could be used in planning agriculture, irrigation management, hydrological decision making, long range weather forecasting and so on. Further more, it is advisable to continue the study with the development of database and to find it relation ship with the weather producing mechanism.

Introduction

Rainfall is one of the climatic parameters that have close bearings on agriculture. It shows systematic and irregular variations over time. These variations play significant role in adapting farming systems, agricultural planning, crop selection and thus productivity. The characterization of these systematic variations will contribute not only in long term agricultural planning but even in long range weather forecasts.

For this purpose long and uninterrupted rainfall data series are required to interpret the results objectively. Then these data series could be subjected to statistical techniques (WMO, 1966) to identify significant cycles and their amplitude. However, as in the case of this study, such a data series is available only to a limited number of stations and hence the detailed statistical test was not applied.

The main objective of this study is to assess whether there is systematic rainfall periodicity.

Materials and Methods

The annual rainfall data for eight selected meteorological stations with a data set of above 40 years were collected. Table 1 indicates the details of stations used in the data set. The length of record in table 1 indicates the number of record years without missing data. They cover all the moisture zones (M2) and rainfall regimes (RR) of the country. Moreover, the mean annual rainfall of these stations varies from stable rainfall type to more erratic type (Engida Mersha, 1999).

The moisture zones classification is based on the studies made by Engida Mersha (2000). The country is subdivided into five-moisture zones namely moist (M), dry sub humid (DSH) semi arid (SA) arid (A) and hyper arid (HA) zones. The delineation of the rainfall regime is based on the classifications made by the National Meteorological Services Agency (1996). According to this classification, four rainfall regimes are identified in the country. These are the mono-modal (M), bimodal type 1(T1b), bimodal type 2 (T2b) and diffused (D) rainfall regimes. The mono-modal rainfall regime is further subdivided into m1, m2 and m3 depending on the onset date and the length of the rainy season. At least one location is selected from each moisture zone with the exception of hyper arid moisture zone, m2 in the mono-modal

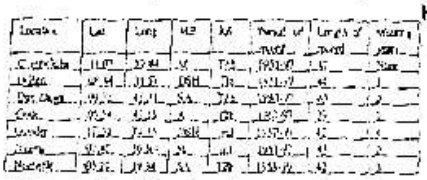

Table 1 Details of stations used in the data set

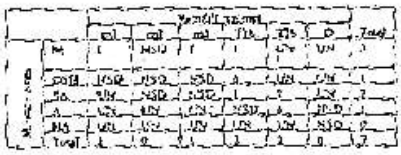

Table 2 Matrix of number of stations used in the data set

rainfall regime and the diffused rainfall regimes. This is because of lack of sufficient data set to represent them (Table 2). The rainfall data include a long series as recommended for climatological assessment by the world Meteorological Organization (WMO, 1983, 1981).

From the annual rainfall data series (R_i) for n years a new series (R_N) was computed as:

$$R_N = \frac{(R_i - R_a)}{R_a} \quad \text{for } i = 1 \text{ to } n \text{ years}$$

Where

R_N-Normalized rainfall difference

R_i - Total annual rainfall, mm for the i^{th} year

R_a-Mean annual rainfall, mm and computed as: $R_a = \Sigma (R_i/n)$

n- Number of years of the rainfall record.

If the value of R_N is below zero, then the rainfall distribution is termed as below normal (BN) and the reverse is true for above normal (AN)

Determination of Rainfall Cyclicity over selected locations in Ethiopia

Engida Mersha Addis Abeba,EARO P.O.Box 2003,

Abstract

Rainfall is one of the climatic parameters that have great importance in rain-fed agriculture. However, it shows systematic and irregular variations over time and space. These variations play significant role in adapting farming systems, agricultural planning, crop selection, and thus productivity. The characterization of these systematic variations will contribute not only in long term agricultural planning but even in long range weather forecasts.

To characterize these variations and assess the cyclic pattern, the annual rainfall data for eight selected meteorological stations have been considered in this study. The main objective this paper is to assess whether there is cyclic trend on the annual rainfall distribution.

The result of the study is encouraging since there appears to be a cyclic tendency in the annual rainfall data. Hence, the results could be used in planning agriculture, irrigation management, hydrological decision making, long range weather forecasting and so on. Further more, it is advisable to continue the study with the development of database and to find it relation ship with the weather producing mechanism.

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For this purpose long and uninterrupted rainfall data series are required to interpret the results objectively. Then these data series could be subjected to statistical techniques (WMO, 1966) to identify significant cycles and their amplitude. However, as in the case of this study, such a data series is available only to a limited number of stations and hence the detailed statistical test was not applied.

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Location	Lat.	Long	MZ	RR	Period of record	Length of record	Missing years
Combolcha	11 05	39 44	M	T1b	1952-99	47	None
D/Zeit	08 44	38 57	DSH	T1b	1951-97	44	3
Dire Dawa	09 36	41 51	SA	T1b	1952-97	43	3
Gode	05 24	43 35	A	T2b	1967-97	29	3
Gonder	12 22	37 41	DSH	m2	1952-97	42	4
Jimma	07 40	36 50	M	m1	1951-97	43	2
Nazareth	08 20	39 24	SA	T2b	1953-91	32	3

Table 1. Details of stations used in the data set

Moisture zones	Rainfall regimes						Total
	m1	m2	m3	T1b	T2b	D	
M	1	NSD	1	1	UN	UN	3
DSH	NSD	NSD	NSD	1	UN	UN	1
SA	UN	NSD	NSD	1	1	UN	2
A	UN	UN	NSD	NSD	1	NSD	1
HA	UN	UN	UN	UN	UN	NSD	0
Total	1	0	1	3	2	0	7

Table 2. Matrix of number of stations used in the data set

From the annual rainfall data series (R_i) for n years a new series (R_N) was computed as:

$$R_N = \frac{R_i - R_a}{R_a} \quad \text{for } i = 1 \text{ to } n \text{ years}$$

Where

R_N-Normalized rainfall difference

R_i - Total annual rainfall, mm for the i^{th} year

R_a-Mean annual rainfall, mm and computed as: $R_a = ?\ (R_i/n)$

n- Number of years of the rainfall record.

If the value of R_N is below zero, then the rainfall distribution is termed as below normal (BN) and the reverse is true for above normal (AN)

rainfall distribution. The zero value indicates a normal rainfall distribution.

Results and Discussion

The results of the assessment whether there is cyclic trend in the mean annual rainfall distribution over selected locations is shown in figures 1 through 3. The results presented here under will be discussed station by station.

Combolcha:

Combolcha is found in the North Wello zone of the Amhara region. It is classified as moist zone with type 1 bimodal rainfall pattern. Two peaks characterize the rainfall. The first and the smallest rainfall peak occurs during April while the major peak is during August.

The normalized rainfall difference for the location during 1952-1997 is shown in figure 1a. Though there are minor ups and downs in the histogram, it is possible to draw a sinusoid curve to indicate a cyclic trend. Hence it is found that it will take about 48 years for the rainfall to cover one cycle (one cycle is defined as the number of years covered by one above normal and one below normal years).

The below normal year that is assumed to begin far ahead the start of meteorological records continues up to 1970. Years marked bold in table 3 indicate the year when meteorological observation started in that particular place. From 1971 to 1994 Combolcha was mainly under below normal rainfall distribution. The expected annual rainfall distribution over the location as of 1995 is above normal (Table 4).

Location	Lat.	Long	MZ	RR	Period of record	Length of record	Missing years
Combolcha	11:07	39:44	M	T1b	1952-97	47	None
D/Zeit	08:44	38:57	Dsh	T1b	1951-97	46	1
Dire Dawa	09:36	41:51	SA	T1b	1953-97	43	2
Ghale	05:54	41:35	A	T2b	1962-97	29	3
Gonder	12:32	37:45	Dsh	m3	1953-97	45	4
Jimma	07:40	36:50	M	m1	1951-97	45	2
Neghelle	05:20	39:34	SA	T2b	1953-97	47	1

Table 4. Percentage of distribution of different rainfall cycles.

Though the area is characterized by AN and BN cycles, there are small ups and downs as shown in Figure 1a. As shown in table 4 the percentage distribution of each cycle within the other cycle i.e. AN within BN or vice versa is computed. The results indicate that there are 42% cases of AN within the BN cycle. This percentage is not computed for the frequency of BN within AN as the AN cycle is not complete.

Dire Dawa:

Dire Dawa is found in the semi-arid zone with bimodal type 1 rainfall pattern. However, the second season is more important relative to the first one. The normalized rainfall difference shown in figure 1b indicates that Dire Dawa is found under a 52 years rainfall cycle. The above normal years are assumed to start far below the start of meteorological record over the area and extend up to 1968. On the other hand, the BN years started in 1969 and extended up to 1994. The second AN cycle starts during 1995 and is expected to continue up to 2021.

As shown in figure 1b, there is certain number of years in the BN cycle with AN characteristics. These account for 25% of the cases (Table 4). The number of cases with BN characteristics in the AN cycle could not be determines as the AN cycles is not complete.

Location	Complete cycle length, years	Duration of		Expected annual rainfall distribution for the next cycle
		Above normal years	Below normal years	
Combolcha	48	1923-1970 1994-	1971-1994	AN
Debre Zeit	46	1963-1983	1951-1962 1984-	BN
Dire Dawa	52	1953-1968 1995-	1969-1994	AN
Ghale	52	1947-1971 1991-	1972-1990	AN
Gonder	40	1953-1964 1988-	1965-1987	AN
Jimma	46	1953-1964 1988-	1965-1983	AN
Neghelle	36	1965-1982	1953-1964 1990-	BN

Table 3. Distribution of above normal (AN) and below normal (BN)

Debre Zeit:

Debre Zeit is classified under the dry sub-humid zone with the same rainfall patterns as Combolcha and Dire Dawa (Table 1). However, the first season is mainly used for the land preparation of crops sown during the second season. Hence, practically there is only one cropping season even though the area is characterized by bimodal rainfall pattern.

The normalized rainfall difference during 1951-1997 indicated in figure 2a shows systematic patterns in the annual rainfall distribution. Therefore, the location is under 46 years rainfall cycle. The first BN cycle started during the start of meteorological record over the area and went up to the year 1962. The second BN cycle started in 1986 and is expected to continue up to the year 2009. On the other hand one complete cycle of AN cycle is observed during 1963-1985 (Table 3). During the AN cycle, the frequency of BN years is about 32%.

Neghelle:

Neghelle is located in the semi-arid moisture zone. It is characterized by a type 2 bimodal rainfall pattern with a distinct dry spell between the two seasons. The first rainy season runs from March to May and the second from September to November. The first rainy season is more prominent, and is very important from the crop production point of view. However, the second season is very important for pasture.

The normalized rainfall difference (Figure 2b) indicates a clear rainfall cyclic trend over the area. Hence, it found that Neghelle is under a 36 years rainfall cycle. There are two BN cases since the period of meteorological record over the area (Table 3). The first BN cycle extends from 1953 to 1964 while the second cycle started in 1983 and is expected to continue up to the year 2001. On the other hand, the AN cycle is observed for 18 years during 1965-1982 with complete cycle. The frequency of BN cases during the AN years is only 5%.

Gonder:

Gonder is a dry sub-humid zone. It is under the influence of mono modal rainfall pattern. A single rainfall peak dominates it. The rainy season extends from June /July to August/September.

As indicated in Figure 3a, it is con-

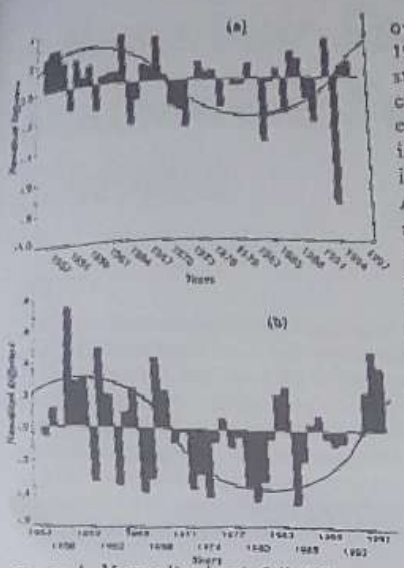

Figure 1. Normalized rainfall difference for (a) Combolcha (b) Dire Dawa

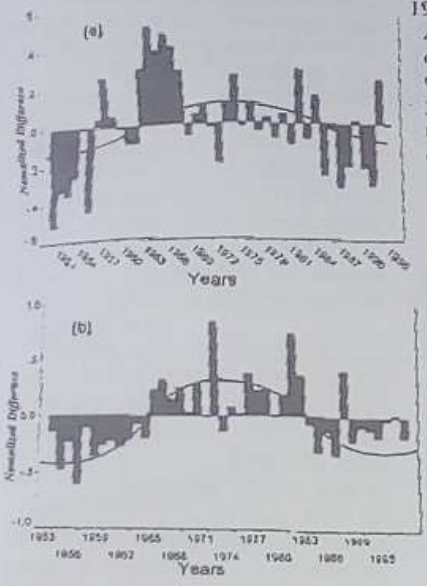

Figure 2. Normalized rainfall difference for (a) Debre Zeit (b) Neghelle

troversial to conclude the cyclic pattern over the area. However, there is more inclination towards cyclic pattern. Hence, it is found that the location is characterized by 46 years of rainfall cycle. The first AN cycle during the period of meteorological record over the location occurred during 1952-1964 while the second started in 1988 and is expected to continue up to the year 2011. BN cycle is observed for 23 years during 1965-1987 (Table 3). Table 4 indicates that the frequency of AN cases within the BN cycle is about 22%. Though the AN cycle is not complete it expected that the location will be under AN rainfall distribution for the next 10 years or so.

Jimma:

Jimma is found in moist zone with mono modal rainfall pattern. The rainy season here runs from February/March to October/ November. It is possible to conclude from figure 3b that the area is under a 46 years rainfall cycle. The first AN cycle extended from 1952 (the start of meteorological record) up to 1964 and the second 1988 to about 2021. One complete AN cycle is observed for 23 year during 1965-1987. However, there is few (21%) number of AN years within this period. This means that within every 5 BN cycle there is 1 year of AN.

Gode:

Gode is classified as an arid zone. The rainfall climatology over the area indicates that it is dominated by bimodal type 2 rainfall pattern with a distinct dry spell between the two seasons. The first rainy season extends from March to May while the second from September to November.

The normalized rainfall difference in figure 3c indicates cyclic trend. Hence it is possible to conclude that the area is under 52 years rainfall cycle. As indicated in table 3 and figure 3c, there are two AN rainfall cycles. The first AN years occur during 1967-1971 and the second during 1997 and is expected to continue up to the year 2023. The BN years are observed for 26 years during 1972-1996. Though AN cycle is not complete as indicated in Table 4 the frequency of AN years with in BN years is 22%.

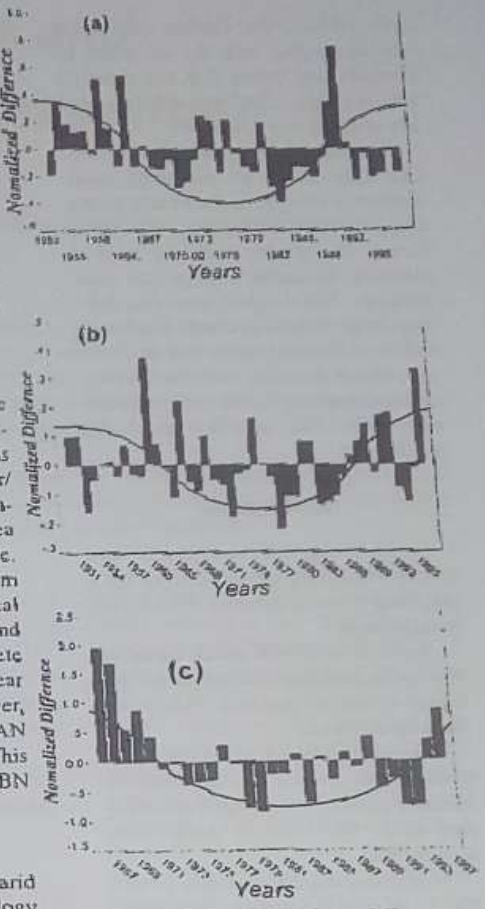

Figure 3. Normalized rainfall difference for (a) Gonder (b) Jimma (c) Gode

Conclusions and Recommendations

Even if the concept of rainfall cyclicity is under discussion and difficult to determine rainfall cycle trial made is this study. The result of the study is encouraging since there appears to be a cyclic tendency in the annual rainfall data.

Hence Gode, Dire Dawa, Neghelle and Debre Zeit show a clear cyclic pattern and are under 52, 52, 36 and 46 years rainfall cycle. Over Combolcha, Gonder and Jimma the cyclic trend are not strong. However, the trial made indicates that these places are characterized by 48, 46 and 46 years of rainfall

cycle respectively. Further more, it is also found that with the exception of Neghelle and Debre Zeit, the expected annual rainfall distribution for the next few years is above normal.

Therefore it is recommended to extend this study by including more number of stations as the results of this study indicate there exists cyclic trend. Hence, the results could be used in planning agriculture, irrigation management, hydrological decision making, long range weather forecasting and so on. Further more, it is advisable to continue the study with the development of database and to find it relation ship with the weather producing mechanism.

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[1] NSD – No sufficient Data

[2] UN – Unsatisfied condition

* Reservoir Sedimentation and Sustainable Sediment Management in Ethiopia

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Abstract

Reservoir sedimentation is not only a major problem for the management of water resources in many parts of Ethiopia, but it has also serious economic impact. Based on 11 existing storage schemes in the country, about a total of 10Mm³ sediment has been deposited each year in the reservoirs, which is equivalent to one medium scale storage reservoir. Suitable storage sites are very scarce and constitute a valuable natural resource that must be protected and used wisely. Thus, water storage reservoirs should be initially designed for sustainable use i.e. for indefinite life on the basis of an integral sediment management approach.

From recent bathymetric survey carried out in 3 reservoirs, 0.24-0.75 % of their storage volume per annum is lost and out of 14 storage reservoirs, 64% of them lose their 30% storage capacity before serving 100 years. In this article sedimentation of 14 storage reservoirs and ways to deal with this problem are briefly discussed.

1. Introduction

Sedimentation of reservoirs is a natural phenomenon following dam construction on rivers and it is mainly related to the natural conditions in a river basin i.e. hydrology, topography, climate, geology, vegetation and human activities. When constructing a dam on a river the flow velocity will decrease and the capability of the river transporting sediment in the reservoir reduces and this consequently result in deposition of material in the storage reservoir which is a growing problem around the World.

World wide it has been found that about 1% of the storage volume of the world reservoir is lost annually due to sediment deposition (Yoon, 1992, Mahmood K. 1987). Similarly, Bruk (1996) estimates the annual loss of storage capacity to be 1-2 % of the worlds total storage capacity. Storage losses in arid regions are doubled reducing the average useful reservoir life 20-30 years (Bruk, 1996). In Sudan 40% of the storages are filled by sediment with an average rate of 1-2.2% annually (Ahmed, 1992) and in India research works revealed that out of 27, actual sediment delivery is higher than predicted in 24 reservoirs ranging from about 1.5 to 3 times the design rate and 16 times higher than the expected rate (Lagwankar et al. 1995).

**This paper was presented on the 4th symposium of "Sustainable Water Resources Development" held July 2001,but due to printing error it was not published. The editorial board upalogizes for the incidence.*

2. Sedimentation in Ethiopian Reservoirs

The rapid sedimentation of water storage reservoirs is a matter of increasing concern in Ethiopia. Some surveys of existing reservoirs that have been carried out in recent years revealed that 0.24-0.74% of storage capacity has been lost annually. The Koka reservoir has been formed as a result of the construction of the Koka Dam in 1959 for developing hydroelectric power. Awash and Mojo are the two main rivers which flow to the reservoir. During the flood season these rivers are heavily laden with sediments. The Sediment deposits in the reservoir have grown to be a serious threat to the intakes at the dam and have already reduced the useful storage volume by 30.3%(Including the year 2000).

One of the oldest and abandoned storage reservoir constructed on the

Reservoir	Basin	Commis. (Year)	Ca.area (km²)	Storage Capacity (Mm³)	Annual Inflow (Mm³)	Total sed.load⁵ (Mm³/yr)	CR	CSR (Yr)	30% Lost (Yr)
Abasamuel¹	Awash	1939	1499	68.8	275	44.90	24	141	42
Alwero	Baro-Akobo	1988	1102	159	1130	16240.14	126	38	
Dire	Awash	1999	77	13	50	8580.26	272	82	
Elwayh	Wabe-Sheble	1996	410	12	55	2700.72	132	40	
Fincha	Abay(B.Nile)	1973	1391	706	432	476.63	775	233	
Gefersa I&II	Awash	1955	57	7.5	25	5170.30	355	107	
Koka	Awash	1960	10747	1667	1002	3331.04	154	46	
Legedadi⁴	Awash	1970	205	45.9	135	7920.94	401	120	
Little beles¹	Abay(B.Nile)	1990	488	5.32	275	12370.02	18	6	
Malkawakena	Wabe-Sheble	1989	4300	763	901	240.98	9697	2909	
Midmar	Tekeze	1998	73	10	10	1166.00	163	49	
Gojeb²	Omo-Ghibe		5350	907	2720	2410.37	1028	308	
Tekeze²	Tekeze		30390	9293	3750	14272.48	287	86	
Gilgel Gibe³	Omo-Ghibe		4225	845	1584	12650.53	211	63	

1: Out of operation
2: Pre-construction stage
3: Under construction
4: the sturage capacity is for the year 1970
5: Including 20% bed load (assumed dry bulk density =1325kg/m³)

Table 1 Some characteristics of the reservoirs

Akaki River is the Aba Samuel Dam. It was constructed in 1939 for hydropower production. Reservoir sedimentation survey was carried out in 1983 after 44 years of service; the average specific sediment yield was estimated as 445 t/km²/yr. However, based on suspended sediment load measurement the specific sediment yield of this catchment was estimated to be 293 t/km²/yr (Sogreah, 1983 Ref. Haferow 1989).

According to a recent bathymetric survey, the capacity of Koka reservoir has bee reduced from 1667Mm³ in 1959 to 1186 Mm³ in 1998 The loss on total capacity over 39 years is 481 Mm³ i.e. 28.8% of the total storage volume. The average annual loss of capacity is 0.74% and annual silting rate is 12.32 Mm³. It was found that about 397.1 Mm³ i.e. 82.6% has been deposited in the active storage.

Based on recent bathymetric survey carried out on three reservoirs; Koka, Legedadi and Gefersa, the storages have been loosing about 0.24-0.74 % of their capacity annually. The suspended sediment yield estimated in these three reservoirs ranges from 431-1109 t/km²/yr.

The above table vividly illustrates the problem of reservoir sedimentation in the country. Because of sedimentation, the country is losing about a total of 20Mm³ storage capacity per annum, which is equivalent to one medium size reservoir. Out of the total 14 reservoirs, 64% of them will lose their 30% storage capacity before serving 100 years. Though they have been designed on the traditional way of 50or100 years life frame (the filling period of dead storage volume is assumed as economic life of a dam), the existing situation reveals that the life of the projects would be ended before their design economic life period. Reservoirs should be planned and operated for indefinite lifetime i.e. the traditional "life of project" approach should be abandoned. The design strategy should be changed from traditional life of project approach to indefinite period, which is compatible with the concept of sustainability. Veltrop (1996) contends that long-term operation of reservoir should be controlled by the life of the civil works, not by sedimentation. He also suggested, an appropriate design life may be from 250-300 years. Morris and Fan (1998), proposed a standard design life of 1000years, referring to the twelve ancient dams that have been functional for more than 2000years.

2.1Possibility of Flushing/Sluicing Sediment from the Reservoirs

The hydrologic size or capacity to inflow ratio, CIR is a primary factor influencing the rate of sediment accumulation and it is also a primary determinant of the types of sediment management techniques that can be used. In order to evaluate sediment problems at preliminary stage and to decide the mode of operation for sediment control, reservoirs may be divided in three groups according to the reservoir capacity to Inflow ratio, CIR (Lysne et al 1995)

CIR>0.3: Many reservoirs in this category will be able to store the incoming sediment loads within the economic life of the reservoir. In some cases density current venting may be applied.

0.03<CIR<0.3: Many reservoirs in this category will be affected by sedimentation within their economic lifetime, but they are normally too big to effectively employ flushing. Drawdown of reservoir during flood season and density current venting may be possible.

CIR<0.03: Sediment inflow can be large compared to reservoir size, but flushing of sediment deposits and drawdown during floods is often possible.

The other empirical approach used for comparing sedimentation problem between different regions is the reservoir capacity to annual sediment inflow ratio (CSR). The CSR is used as a measure of sedimentation problems. CSR, in other words is the time it takes for the reservoir to fill completely if all incoming sediment deposits in the reservoir.

The Capacity-Sediment inflow ratio of a reservoir is:

CSR: Capacity – Sediment inflow ratio (years)

E: Annual sediment yield (t/km²/yr)

$$CSR = \left(\frac{E}{R} * (1 + B_f)\right)^{-1} * \rho_b$$

B_f: Bed load as fraction of suspended load

ρ_b: Dry bulk density of sediment deposit

Fig.1 illustrates the mode of operation with regard to flushing and sluicing operation to reduce sedimentation. Basson and Rooseboom (1996), suggested that reservoirs designed and operated for sedimentation control should fall in the bottom left hand quadrant with CSR<100 and CIR <0.2, these reservoirs have excess water to allow hydraulic sediment control measures. If CIR >0.2, the reservoir doesn't have enough excess water for flushing/sluicing and reservoir draw dawn. For such cases, density currents and venting is practiced only in some areas. Recommended values for successful flood flushing is when CIR<0.03.

Thus, according to the above recommended mode of operation, out of the fourteen storage sites, only one reservoir, (Little Beles, CIR=0.02 and CSR=18) has the possibility of sediment reduction through sluicing/flushing and all the rest are out of the range

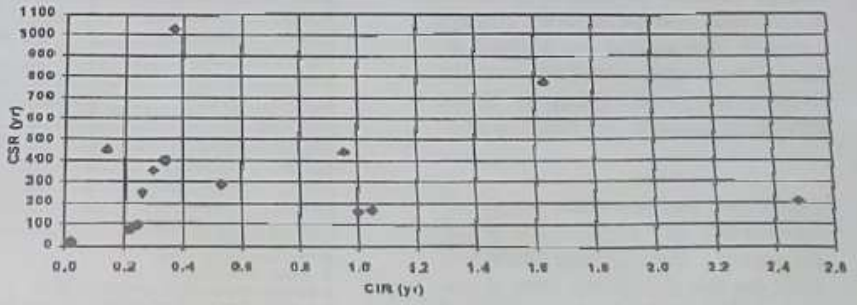

Fig.1 CSR & CIR to evaluate the mode of operation

which needs other alternative measures to reduce their sedimentation problems.

2.2 Strategies for Dealing with Reservoir Sedimentation

Because of the many variables involved in reservoir sedimentation problems, no single control measures can be suggested. The control measures can be grouped in main categories as: control of watershed, control of inflow sediment, control of deposition, removal of sediment deposits and accepting sediment inflows.

The following four main strategies are recommended to reduce sedimentation problem in storage reservoirs (Basson and Roosebom, 1996).

1.Minimize sediment loads entering the reservoir through;

*Soil and water conservation programme.

*Upstream trapping of sediment (debris dams or vegetation screens).

*Bypassing of high sediment loads (bypass tunnel or channel, or off-stream storage that allows floods to be passed in the river)

2. Minimize deposition in reservoirs through;

* Drawdown and sluicing: passing sediment-laden flows through the reservoir by means of drawing down the water level.

* Venting density current.

3. Removal of accumulated sediment deposits through;

*Flushing by drawing down the water level (in many cases emptying the reservoir), during floods or in the rainy season.

*Mechanical excavation or dredging

*Conventional hydraulic dredging

*Hydraulic dredging by use of gravity. (Transport of sediment in pipeline or by free surface flow in channels or tunnels).

4. Compensating for reservoir sedimentation;

* Maintain long-term storage capacity by raising the dam

* Abandon or decommission the silted reservoir and construct a new reservoir

* Import water from elsewhere

The technical, economic and environmental feasibility of the above measures depends on the number of site-specific factors as discussed below.

*Availability of suitable bottom outlet facilities

*Availability of surplus water for flushing

*Characteristics of surplus water for flushing

*Purpose of storage and water demand

*Topographical features of the reservoir area

*Consequences of control measures interfering with reservoir operation

*Characteristics of deposited material

*Environmental impact, such as; consequences of flushing/dredging sediment disposal

3. Incompatibility of Traditional Cost-Benefit Analysis for Sustainable Development

Discounting is a time adjustment procedure used to compare the value of future costs and benefits occurring at different points in time. The longer into the future the costs and benefits occur and the higher the discount rate, the lower are the present value of the costs and benefits.

Reservoirs are often designed for a lifetime of 50 or 100 years and their design is usually influenced not by the durability of construction material, but the traditional Cost-Benefit analysis and its use of a discount rate to compare all costs and benefits on a present value (PV) basis. Such procedures discourage additional construction costs, for example, installation of sediment flushing facilities such as large low-level outlet that may not be used for several years. This approach implies that one accepts large costs in the future, either due to decommissioning, reconstruction or to lost water storage capacity. This indicates that the traditional method of Cost-Benefit analysis is not compatible with sustainable design and operation of reservoirs.

The discount factor for finding the present value of costs and benefits occurring at a specified point of time in the future is given by:

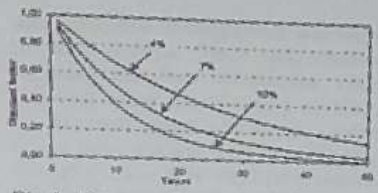

Fig 2: Discount factor for finding the present value of future costs and benefits as a function of time. Discount rates of 4, 7, and 10%

$$d_r = (1 + r)^n$$

d_r discounted factor
r discount rate
n the point of time into the future when the costs and benefits occur.

Costs related to sedimentation in reservoirs often occur long time after construction. From Figure 2 it can be seen how discount factors are reduced with time. For instance, at a discount rate of 10%, the discount factor after 50 years is only 0,009. This means that less than 1 Birr can be invested at present to prolong the reservoir service life and to avoid a cost of 100 Birr after 50 years. Discounting involves discrimination of future generations because projects with short term benefits and long term costs are more likely to be undertaken, thus leaving the costs to future generations, and the reverse, projects with present costs and future benefits are less likely to be undertaken. Thus, it may be argued that environmental and sustainability concerns should be given more weight by lowering the discount rate for projects that have large environmental or sustainability impacts

4. Conclusions and Recommendations

In design of storage reservoirs, sustainability should be considered from the initial phase of project design, assessing the greatest possible sediment management alternatives, which will eventually lead to long-term sediment balance. Because of increasing population, which occupies more land for settlement and farming, combined with the environmental concerns, and increasing construction costs makes

reservoir development difficult. Thus, constructing small storage reservoir with sustainable sediment management is economically more desirable than constructing large reservoir by providing a dead storage zone in the deepest part of the reservoir. Moreover, the traditional discounting technique should be modified in such a way that future generations and environmental impacts are considered whenever projects, like storage reservoirs are designed.

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