water

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Special Issue

Proceeding of the Symposium on Sustainable Water Resources Development

Arbaminch

3 - 4 July 2000

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The Ethiopian Journal of Water Science and Technology, named "Water" is intended for publication of research results in the water sector. It enables researchers, engineers, experts, managers, etc., publish their findings and enlighten others concerned through their results.

This proceeding is a special issue of Water and is the outcome of the 4th symposium on "Sustainable Water Resources Development" held from the 3rd to 4th of July 2000 at Arbaminch Water Technology Institute (AWTI). The symposium has been organized by AWTI and co-sponsored by German Development Cooperation (GTZ) and AWTI.

From a large number of papers received by the symposium organizing committee, 18 papers have been accepted for presentation in the symposium. These papers obviously can't be inclusive of all aspects of water resources development, but they deal with wide ranges of topics and present various findings and study results, which are mainly relvant to Ethiopia.

The editorial board and myself are thanking all the authors for their contributions. The editorial board encourages and invites all interested to use the forum of Water to publish research results. The special issue of Water, as a symposium proceeding, is published annually. All interested can contribute either to the research journal or to the symposium proceeding.

Dr.-Ing Seleshi Bekele
Editor

Application of System Approach at Micro Level Planning in Water Resources Engineering

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Abstract

The task of water resource system planners may be broadly described as the identification or development of possible water resource system designs or management plans and evaluation of their economic, ecological, environmental and social impacts. The emphasis of this paper is on optimization models that can be used to identify those management plans which best meet society's objectives. Four cases are also discussed in detail to illustrate the approach in more comprehensive way.

Introduction

Water resources development may be considered at two scale - macro and micro. Macro developments consist of the traditional technological activities such as construction of hydro - electric plants, dams, canal and other hydraulic structures. Micro scale activities consist of the set of activities for carrying the water from the major conveyance system to field level till utilization by crops or to carry the potablewater from sour to destination point. Although attention has mostly been given to macro scale developments but micro scale activities may be comparatively more useful from marginal cost benefit and employment generation considerations. Furthermore, when we note that efficiency of the system is of the order of 20 to 50 percent due to losses at the micro scale, the importance and scope of development at this level becomes significant because of increasing scarcity of water resources.

Major planning issues at micro level are :

(I) Optimum decisions for lining the water courses

(II) Conjunctive use of surface and ground water with decision on appropriate ground water technology in the context of optimum policy of water applications and optimum cropping pattern,

(III) Precision land levelling. Optimization models have been developed for each of these activities, individually and integrally, and a case study has been carried out for a micro level system in punjab, India (Khepar, 1980, Chaturredi and Khepar 1981).

(IV) Optimum diameter of the pipe to meet the discharge and pressure requirement at demand points in the water distribution system, Singh, R.K. and Shir Prwad (1995).

Case 1 , 2 and 4 are hypothetical in nature which illustrate at the planning stage decision analysis case 3 is real life problem the analysis is done for punjub, India the finding of these cases are discussed in more detail.

(I) Lining of Water Courses : A water course is a sub canal which takes off from a main canal and is used for diverting water to different farmers' fields in its command area. Of the total water loss in the distribution system seepage loss in the water course is propartionately very high because the wetted perimater per unit of discharge is comparatively high. A major portion of the total seepage of a canal network may thus be controlled if the water courses are lined.

The water from the water course is supplied to the farmers according to a certain time schedule in turns. Thus the different reaches of the watercourse run for different times. The upper reaches run for a longer time than the lower ones and hence total seepage losses are higher in the upper parts. The annual saving of water per unit length, thus decreases with increasing length of water course. However, the cost of lining per unit length of the watercourse remains constant as the channel section remains the same. Therefore, water saving benefits of lining the water course decrease with increasing length to be lined. With limited funds, instead of lining the whole length of each watercourse as currently practiced, much greater benefits could be obtained by lining optimum length of different water courses which are competing for lining. The problem is complicated as the water course constitutes a network of varying lengths, each operating for a different time and there by having different benefit functions in terms of saving of water. A solution can, however, be obtained using linear programming or dynamic programming problems Singh, R. K. and Shiv pressed (1995).

The objective function can be specified as maximization of benifit from lining water course with a given restriction on the availability of funds. The decision variables are the lengths of each water course which give the maximum net benefit as a result of lining. For the linear programming problem (LPP) the objective function is :

Objective function:

$$\text{Max } f = \sum_{i=1}^{n} \sum_{y=1}^{s} a_{ij} Lij - Cij\, Lij$$

Constraints:

Subject to $$\sum_{i=1}^{n} \sum_{j=1}^{s} I_{ij}\, Lij \le I$$

$$Lij \le L_{ii}$$

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Non negativity constraints :

Iij 0

Lij 0

Here

aij = annual benefit per unit length of the i th water course in the j th reach

Lij = Length of i th reach of the i th water course

cij = Annual cost per unit length of the i th course in the i th reach

Iij = Investment per unit length of the i th water course in the i th reach

I = Total investment available

$\overline{L}$ ij = Maximum length available of the i th water course in the i th reach.

The LPP can be used to find out the optimum lengths of the water courses which give the maximum benefits.

2.Optimum Ground water Allocation for Various Cropping Pattern:

In India two management practices have been adopted for groundwater management. One is large deep tubewells of one cusec serving about twenty to forty hectare managed by the state. The others are small low capacity tubewells, owned by individual farmers. Large tube wells require higher initial investments but per unit of water delivered and both capital and recurring costs are less than for small tubewells. The small tubewells run, however, be easily developed and are under the control of individual farmers. Both have their own advantages and disadvantages.

The linear programming problem (LPP) formulation of the problem to maximize the annual net return subject to constraints on the availability of water and other inputs are given below :

$$\text{Max } f = \sum_{i=1}^{n}\sum_{j=1}^{2}\sum_{k=1}^{4} a_{ijk} x_{ijk} - \sum_{j=1}^{2} C_j S_j - \sum_{j=1}^{2} \overline{C}_j (1+L_r) T_j - \sum_{j=1}^{2} G_j (1+L_r) T_j$$

Here

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

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

j = 2 for summer season

k = level of irrigation 1 to 4

a_{ijk} = net return in rupees per hectare excluding cost of irrigation and gyp x sum from crop i grown in season j with level of irrigation k

x_{ijk} = area allocated in hectares to crop i grown in season j, with level of irrigation k.

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

S*j = surface water allocated in ha-mm in season j

$\overline{C}_j$ = cost of applying one ha-mm of tubewell water in season j

Tj = tube well water allocated in ha-mm in season j excluding leaching requirements

Gj = cost of applying gupsum per ha-mm of tubewell water

Lr = Leaching water requirement in fraction.

Subject to

(I) Water requirement Constraint :

Here Wijk = water required in ha-mm by crop i, grown in season j with level of irrigation, k.

$$\sum_{i=1}^{n}\sum_{k=1}^{4} X_{ijk} W_{ijk} - S_j - T_j(1+L_r) = 0 \quad \text{Vj}$$

(II) Land area constraint :

$$\sum_{i=1}^{n}\sum_{k=1}^{4} \propto_i x_{ijk} \le Aj \quad \text{vj}$$

Here ; ai = land area occupying coefficient for crop activity i; ; is equal to 1 , if crop is grown in season j; , otherwise it is zero and Aj = total land available in ha in season j.

(III) Water availablity constraint :

(a) Surface water

Sj £ A Sj Vj

(b) Tubewell water

(1+Lr) Tj £ A Tj Vj

Here, ASj = surface water available in ha-mm in season j, after allowing for losses, and ATj = tubewell water available in ha-mm in season j, after allowing for losses.

(IV) Maximum allowable area:

$$x_{ijk} \le Aij$$

Here , Aij = maximum area in ha available for allocation to crop i in season j

(V) Minimum allowable area :

$$x_{ijk} \ge \overline{A}ij$$

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

Land leveling :The soil acts as a water reservoir for crops land leveling is the grading of land to a smooth level or uniformly sloping fields which ensures efficient irrigation water use and crop growth. A lower level of precision in leveling of fields results is spatial variation of moisture distribution in profile, the extent being dependent upon the non uniformity in topography. Under irrigation develops moisture stress in the root zone, while over irrigation leads to deep per collation losses. Thus, non-uniform topography results in low water use efficiency. The main advantages of proper land leveling are improved irrigation efficiency, uniform soil moisture for germination, increase in cultivable land, reduced delivery losses and overall higher yield. It was found that the average yield of wheat and maize crops at different levels of the topography index may be given by expressions of the following form

$$Y = ae^{bTI}$$

Here , Y = Yield in quintals /ha

TI = Topography index

a,b = are the regression coefficients

The benefit and cost functions were determined and had the following forms

$$B = a_1 \ TI^{b1}$$

$$C = a_2 \ TI^{b2}$$

Here , B = Annual benefit

C = Annual cost

a_1, a_2, b_1, b_2 = Coefficients

These expressions for specific situations may be used to find the optimum investment.

Integrated Micro level planning: In preceding sections efforts were made to develop optimum decisions for individual irrigation water management alternatives. If there is no constraint on funds, every alternative should be executed at a level which gives the maximum constraint returns. However, when there is a constraint on funds and the different alternatives are competing for allocation of funds, investment decisions for each held to be developed for maximizing the returns.

A linear programming model has been developed for this purpose. Cost benefit functions for each alternative have been developed earlier.

The objective function

$$M_{ax\,R} = \sum_{i=l}^{n} \sum_{j=l}^{s} \left(Y_{ij}\,\overline{C}_{ij}\right)$$

$$\text{Sub - to} \sum_{i=1}^{n} \sum_{j=1}^{s} \overline{C}_{ij} \leq I$$

$$\overline{C}_{ij} \leq \overline{a}_{ij}$$

and $\overline{C}_{ij} \geq 0$

Here,

Yij = annual return per unit of investment on i^{th} alternative at the j^{th} level

$\overline{C}_{ij}$ = investment on the i^{th} alternative at the j^{th} level

I = Total investment available

$\overline{a}_{ij}$ = Maximum investment posssible on the i^{th} alternative at the j^{th} level.

i = 1 to n (irrigation water management alternatives)

j = 1 to & (levels of alternative investment on each alternate)

Following Four cases illustrate the preceding concepts indetail.

Case1: A farmer owns a 100 acre farm and plans to plant at most three crops. The seed for crops A , B and C costs $ 40, $ 20 and $ 30 per acre respectively. A maximum of 3,200 can be spent on seed, crop A , B and C require 1,2 and 1 workdays per acre respectively and there are a maximum of 160 workdays available. If the farmer can make a profit of $ 100 per acre on crop A, $ 300 per acre on crop B, and $ 200 per acre on crop C how many acres of each crop should be planned to maximize profit.

Problem Formulation :

Maximize $P = 100x_1 + 300x_2 + 200x_3$

Subject to:

$x_1 + x_2 + x_3$ £ 100

$40x_1 + 20x_2 + 30x_3$ £ 3200

$x_1 + 2x_2 + x_3$ £ 160

x_1, x_2, x_3 ³ 0

Here x_1, x_2 , x_3 are the decision variables which corresponds to number of acre of crop A, B and C are to be planned and P is total profit. After applying simplex algorithm on the problem it has been obtained that 60 acres of crop B, 40 acres of crop C and no crop A will maximize the profit as $ 26,000 and slack of 800 $ can be used for some other purpose.

Case 2: It is desired that to build an aqueduct to convey water from point 1 to 10. From point 1, the route may extend to point 2, 3 or 4. From one of these points, the route proceeds to 5, 6 or 7 then to 8 or 9 and finally to 10. The schematic arrangement is shown in following figure, which also shows the cost of the route between any two points considered in million of $.

There are 18 possible permutations. In the route formation 1 to 10 (3 * 3 * 2 * 1), each could be valued and least cost solution selected. Dynamic programming reduces to evaluation process by an ordered procedure

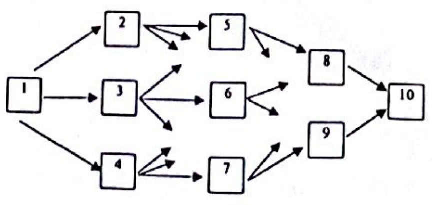


Figure 1 (a) Different possible routes between two terminal points

	2	3	4
1	2	4	3

	5	6	7
2	7	4	6
3	3	2	4
4	4	1	5

	8	9
5	1	4
6	6	3
7	3	3

	9
8	3
9	4

Figure 1 (b) Cost between two alternative route in million dollars.

The least cost solution using dynamic programming 11 million $ along the route 1-3-5-8-10, 1-4-5-8-10 and 1-4-6-9-10.

Case 4 : A water distribution system transports water from sources of supply to various demand points. A system consists of sources of water supply. Pumping stations and demand nodes for water, all connected by pipe lines. In a city of moderate size, there may be number of supply centres and thousands of demand points. For the sake of simplicity, a small system will be used as an example. Fig.2 shows the system where there are one supply centre, three demand points, and one pumping station.

Detail of branching network layout

A linear programming formulation for an optimal design of a water supply system is presented by Gupta (1) wherein the cost of pipes in a given pipe network satisfying customers' demand for water is minimised. Work on optimal design and operation of water distribution systems upto 1973 has been reviewed by Shamir (2). Subsequent works in this area are those by Watanatada (1973), Hamberg (1974), Rasmusen (1976), Bhave (1978), Bhave (1983) and Martin (1988). I have shown here how a large linear programming problem for a water distribution system can be solved by means of decomposition principle. To the best of my knowledge solving linear programming problem for a water distribution system presented in this paper is first to incorporate the optimisation fo water distribution system by decomposition principle.

The decomposition principle is a procedure for solving large linear programs that contain constraints of special structure. The constraints are divided into two parts: general constraints and constraints with special structure.

The strategy of the decomposition principle is to operate on two separate linear programs: one over the set of general constraints and the other over the set of special constraints. The linear program over the general constraints is called the master problem, and the linear program over the special constraints is called the subproblem. The information

Case 3:

Table : 1 Comparison of Alternative Technology and Decisions

S.No	Description of Water management alternative	Maximum Water available (ha-mm) Surface Tubewell		Water used (ha-mm) Surface Tubewell		Surface Tubewell	Water un used (ha-mm)	Cropping Intensity	Net Return	Percent increase in net return
1.	Existing cropping pattern with low capacity tubewells	90515	58059	90515	58059	-	-	148	758061.43	-
2.	Optimum cropping pattern using fixed yield approach and low capacity tubewells	90515	58059	90515	58059	-	-	154	914015.36	21
3.	Optimum cropping pattern using fixed yield approach and high capacity cooperative tubewells	90515	58059	90515	58059	-	-	154	949431.35	25
4.	Optimum cropping pattern using alternative levels of irrigation water and low capacity tubewells	90515	58059	90515	40291	-	17768	190	1094337.36	44
5.	Optimum cropping pattern using alternative levels of irrigation water and high capacity cooperative tubewells	90515	58059	90515	58059	-	-	190	1126905.01	49

Source : Khepar (1980)

is passed bback and forth between the two linear programs until a point is reached where the solution to the original problem is achieved.

1.Problem formulation :

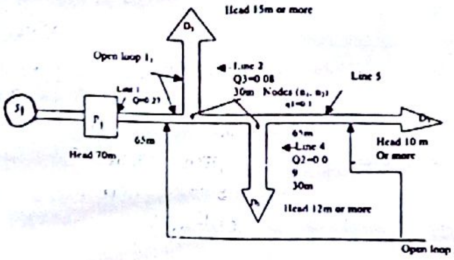
Take S_1 as a source of water supply, and D_1, D_2, D_3 be three demand points. D_1 requires a net head to 10.0 m or more with discharge rate of 0.10 m^3 per second. D_2 requires a net head of 12 m or more with discharge rate of 0.09 m^3 per second. D_3 requires a net head of 15 m or more with discharge rate of 0.08 m^3 per second. Pump P_1 generates a head of 70 m. General layout of the network is shown in Figure 2. Source S_1 is big enough to meet water demands of D_1, D_2 and D_3. The different pipe sizes available are 10 cm, 15 cm, 25 cm and 40 cm in diameter. Cost of these pipes per m length is \$.3, \$4, \$6 and \$8 respectively. Neglect minor losses in the fittings.

The problem is to design an optimum pipe network using decomposition principle.

First Step : **Detail of the problem.**

Referring to Fig.2, the following can be concluded about the network : there are two nodes n_1 and n_2; there are three open loops, loop 1_1, 1_2 and 1_3; there are five lines, lines 1, 2, 3, 4 and 5.

Fig. 2 Detail of branching network layout



Let us number the lines as shown in Figure 2.

Second Step : **Find discharge rates throughout the network.**

Discharge rates in lines 2, 4 and 5 are known. Applying the continuity equation discharge in line 1 = 0.08 + 0.09 + 0.1 = 0.27 cubic m per second and line 3 = 0.27 - 0.08 = 0.19 cubic m per second.

Third Step : **Values of the coefficient can be computed for each pipe diameter by making use of Hazen-William's formula. Table 2 gives various values of S, obtained from equation 1.**

Hazen-William's formula used is given as

Where

hf = Head Loss (m)

q = Rate of flow (m^3/s)

C_{hw} = Hazen William's coefficient (130 in my case)

L = Length of pipe (m)

D = Diameter of pipe (m)

S = Coefficient of friction using above equation, values of S are given in Table 2.

Fourth Setp : Calculate maximum allowable friction losses in each open loop.

Maximum allowable friction haed loss in open loop 1_1 = 70 - 15 = 55.

Maximum allowable friction head loss in open loop 1_2 = 70 - 12 = 58.

Maximum allowable friction head loss in open loop 1_3 = 70 - 10 = 60.

Fifth Step : Set up restriction. L_{ij} will be the length of pipe where first subscript denotes line and second subscript denotes for diameter, i = 1 to 5, j = 1 to 4.

Since there are three open loops and five lines, the total number of restrictions will be eight.

1. Loop l_1 (consists of lines 1 and 2) :

$[1.18 L_{11} + 0.29 L_{12} + 0.04 L_{13} + 0.01 L_{14} + 0.12 L_{21} + 0.03 L_{22} + 0.004 L_{23} + 0.001 L_{24} + 0.0 L_{31} + 0.0 L_{32} + 0.0 L_{33} + 0.0 L_{34} + 0.0 L_{41} + 0.0 L_{42} + 0.0 L_{44} + 0.0 L_{51} + 0.0 L_{52} + 0.0 L_{53} + 0.0 L_{54}1]$ £ 55

2. Loop l_2 (consists of lines 1, 3 and 4) :

$[1.18 L_{11} + 0.29 L_{12} + 0.04 L_{13} + 0.01 L_{14} + 0.0 L_{21} + 0.0 L_{22} + 0.0 L_{23} + 0.0 L_{24} + 0.62 L_{31} + 0.15 L_{32} + 0.02 L_{33} + 0.003 L_{34} + 0.155 L_{41} + 0.038 L_{42} + 0.0053 L_{43} + 0.0013 L_{44} + 0.0 L_{51} + 0.0 L_{52} + 0.0 L_{53} + 0.0 L_{54}]$ £ 58.

3. Loop l_3 (consists of lines 1, 3 and 5) :

$[1.18 L_{11} + 0.29 L_{12} + 0.04 L_{13} + 0.01 L_{14} + 0.0 L_{21} + 0.0 L_{22} + 0.0 L_{23} + 0.0 L_{24} + 0.62 L_{31} + 0.15 L_{32} + 0.02 L_{33} + 0.003 L_{34} + 0.0 L_{41} + 0.0 L_{42} + 0.0 L_{43} + 0.0 L_{44} + 0.19 L_{51} + 0.05 L_{52} + 0.01 L_{53} + 0.002 L_{54}]$ £ 60

4. Line 1_1 :

$$L_{11} + L_{12} + L_{13} + L_{14} = 65$$

5. Line 1_2 :

$$L_{21} + L_{22} + L_{23} + L_{24} = 30$$

6. Line 1_3 :

$$L_{31} + L_{32} + L_{33} + L_{34} = 65$$

7. Line 1_4 :

$$L_{41} + L_{42} + L_{43} + L_{44} = 30$$

8. Line l_5 :

$$L_{51} + L_{52} + L_{53} + L_{54} = 65$$

9. $L_{ij} \geq 0, i = 1 \text{ to } 5, j = 1 \text{ to } 4$:

Sixth Step : Set up objective friction using equation.

$$F\min = (3L_{11} + 4L_{12} + 6L_{13} + 8L_{14}) + (3L_{21} + 4L_{22} + 6L_{23} + 8L_{24}) + (3L_{31} + 4L_{32} + 6L_{33} + 8L_{34}) + 3L_{41} + 4L_{42} + 6L_{43} + 4L_{44}) + (3L_{51} + 4L_{52} + 6L_{53} + 8L_{54}).$$

Seventh Step : By making use of decomposition principle to get optimum values of lengths, Table 3 gives the final results. The solution was reached after 5 iterations.

Table 3 :

Values of Length		
L_{11}	0	
L_{12}	65	
L_{13}	0	
L_{14}	0	
L_{21}	30	
L_{22}	0	
L_{23}	0	with objective = $665.221
L_{24}	0	
L_{31}	35	
L_{32}	30	
L_{33}	0	
L_{34}	0	
L_{41}	30	
L_{42}	0	
L_{43}	0	
L_{44}	0	
L_{51}	65	
L_{52}	0	
L_{53}	0	
L_{54}	0	

Line 1 consists of 15 cm diameter pipe 65 metere long. Line 2 consists of a 10 cm diameter pipe 30 metre long. Line 3 consists of a 10 cm. Diameter pipe 35 metre long and 15 cm. Diameter pipe 30 metre long. Line 4 consists of 10 cm. Diameter pipe 30 metre long. Line 5 consists of 10 cm. Diammeter pipe 65 metre long.

Conclusions

The suggested models could be used for allocation of funds for different irrigation water management alternatives for maximizing the return selecting optimum and pipe sizes in designing the water distribution system for minimum cost when there is a constraint on availability of funds. The data required include the investment response function for each alternatives.

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Microcomputer Programs For Planning Sustainable Water Resources Development Projects In Ethiopia

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Abstract

In planning sustainable WRD projects, the framework for analysis has two components. These components are *conceptual* and *computational framework for analysis*. A simple computational framework for analysis has been developed using MS-Windows based LOTUS 1-2-3 Release 5.0 spreadsheet macro-programming for a hypothetical river basin (but it resembles in many ways the Incomati River Basin of Mozambique). The computational framework for analysis includes AWTIBCI, AWTIAGR, AWTIPWS, AWTIRRS, AWTIYLD, and AWTISTRAT. These models have been developed based on the algorithm developed by Koudstaal et. al (1995) to work under the classic MS-DOS based LOTUS 1-2-3 and symphony spreadsheet packages.

AWTIBCI supports a screening of alternative individual irrigation projects under the assumption that water is abundantly available. The indicators that can be used through this model are NPV, IRR, B/C ratio, N/K ratio, investments and maintenance costs, agricultural production, employment and farmers income. Promising projects can be selected for further strategy formulation. *AWTIAGR* estimates monthly water demands for individual irrigation projects taking into account: (i) a specific cropping pattern and corresponding crop water use coefficients (K_c coefficients); and (ii) specific precipitation and evaporation data. Resulting water demand data provide an input data into AWTIRRS model. *AWTIPWS* estimates monthly water demands for public water supply for individual urban areas for three different scenarios: average, low and high. These scenarios combine respective estimates of: (i) actual population; and (ii) population growth factors. *AWTIRRS* simulates water flows in monthly time steps in a river-reservoir system, matching demand and supply through the operation of reservoir. Through the application of reservoir operating rules a reservoir release is determined as a function of the water available at the beginning of the month. Subsequently, water is allocated to the different use categories: irrigation, public water supply (PWS), hydropower and low flow requirements. *AWTIYLD* estimates consequences of water shortages in terms of: (i) the yield reductions for selected crops; (ii) expected financial and economic damages; and (iii) reductions in employment and farmer's income for four selected irrigated areas. *AWTISTRAT* supports the formulation of strategies, enabling analysts to place the infrastructural components of a strategy in a proper time frame and calculating the impacts in terms of main indicators. The infrastructure components are the reservoir; four irrigation projects; a hydropower plant; the recharge facilities for the dunes; and the PWS connections.

The results of the above models will be used in preparing score cards for the various formulated strategies and a decision support software like *EXPERT CHOICE* can be used for final decision. In fact for each of the above programs there are several commercial software. But most commercial software do not exactly fit with one's specific problem. Therefore, the primary objective of this research project is to disseminate the use of spreadsheet macro-programming in planning sustainable WRD projects in Ethiopia. Based on which, planners will be able to understand the physics of the analysis. However, if one uses commercial software, then one may not be able to fully understand the physics of the analysis.

1.Introduction

The key reason for the failure of several irrigation and drainage schemes, and the inability to exploit surface and groundwater resources to a sustainable level is poor planning, design, system management and development. This is partly due to the inability of engineers, planners and managers to adequately quantify the effects of their interventions on the water resource system and to use theses effects as guidelines for achieving a better planning and design, and to facilitate improved management.

A major constraint to the development of such a strategy is the complexity of the water resource system, a complexity that microcomputers are now able to handle. For underdeveloped countries like Ethiopia, absence of guidelines manual and microcomputer programs for planning WRDP is by far the major constraint. Until recently, almost all water resources development projects in the country have been planned, designed and constructed by foreign consultants and contractors. Eventhough, the country spent a lot of hard currency (through loan) for these consultants and contractors, most of the time, the output of their work has not been found satisfactory to alleviate the nation's deep-rooted problems.

In an attempt to solve these problems, the Federal Government of Ethiopia has shown great effort to establish regional organizations like SAERT, SAERAR, SAERSAR, etc. to undertake consultancy and construction services for WRDP in their respective regional states. These organizations started their activities almost from scratch with limited experienced skilled manpower and logistics. Quite a large number of AWTI's graduate water engineers are working for these organizations.

It is this situation that initiated this project. Therefore, the main objective of this project is to prepare simple microcomputer programs for planning water resources development projects, both at the feasibility and planning stage that could serve as a training computational module for the Water Resources Planning and Management (WRPM) course offered at final year in AWTI. This will help AWTI graduate water engineers to learn the importance and the skill of spreadsheet macro-programming for proper WRPM. This way the objective of this research project will be disseminated to the country. In fact, the microcomputer models have become a computational module for the WRPM course starting from May 2000. Feedback from the students & practicing engineers are being received and based on which the models have been modified. This process will continue and will obviously lead to AWTI having a WRPM software suitable to the Ethiopian condition.

The methodology for this research project is to customize the general principles of framework for analysis (Koudstaal et al., 1995) and prepare computational framework for sustainable planning of WRDP that will lead to an integrated water resources management. Analysis, as referred to in this paper, supports planning for integrated water resources management. Analysis of water resources problems supports planning for integrated WRPM involves different steps which can be taken in the process of formulating, analyzing, evaluating, and presenting alternative strategies. The final aim of analysis in this respect is to generate *quantitative information* to enable better decisions on proposed actions for water resources development. The complexity of such analysis is increasing, not only because of the changing scope of WRPM - which forces water resources planners to deal with new disciplines - but as well because of the developments of predictive modelling techniques and computers. Analysis for planning does not require detailed and complicated simulation models that we require for fundamental research purpose. What is required are flexible planning models which enable analysts to produce information on impacts of a

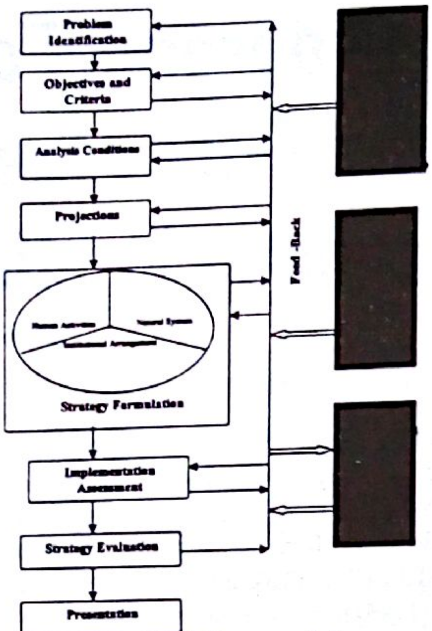

Fig. 1 Conceptual Framwork for Analysis

wide variety of alternative options under often substantial uncertainties, for example with respect to economic developments and natural system behavior.

Planning for WRPM requires an analysis that responds to questions asked by decision-making agencies. It should be *problem oriented*, carefully tuned to the decisions to be made, which in contrast to fundamental analysis which has the objective to understand social, economic or physical processes. Impacts of proposed actions, which the analysis aims to quantify, might encompass a wide range of effects on, e.g., natural systems, the national economy, the economy of different water use categories, the costs of measures and institutional arrangements. *Economic and natural system analyses are the basic components of any study to support planning decisions*. Overall organization and presentation of all relevant effects require rather strict arrangements and the understanding of basic principles of planning and evaluation of alternative courses of action.

The various steps of analysis are generalized in two components, the *conceptual framework* and the *computational framework*. Guidelines for structuring the steps to be taken regardless of the specific problem are presented by the conceptual framework (Fig. 1). The computational framework (Fig. 2) on the other hand links a set of computational tools, such as databases and computer models, and formulates a set of operation rules for these tools and their interactions.

The computational framework for analysis includes AWTIBCI, AWTIAGR, AWTIPWS, AWTIRRS, AWTIYLD, and AWTISTRAT. These models have been developed based on the algorithm developed by Koudstaal et. al (1995) to work under the classic MS-DOS based LOTUS 1-2-3 and symphony spreadsheet packages for the schematized hypothetical river basin (Fig. 3).

2. The Models

2.1 AWTIBCI: model for benefit - cost analysis of individual agricultural projects

Purpose: AWTIBCI supports a screening of alternative individual irrigation projects under the assumption that water is abundantly available. The indicators that can be used through this model are NPV, IRR, B/C ratio, N/K ratio, investments and maintenance costs, agricultural production, employment and farmers income. Promising projects can be selected for further strategy formulation.

Model operation: The following steps should be followed to operate the AWTIBCI spreadsheet model. (i) Fill out those input tables that differ for each run: project area and irrigation efficiencies (Table IN1); cropping patterns (Table IN2); and time schedule of implementation (Table IN3). These tables are to be filled with data on the WITH and WITHOUT situation. For WITH conditions, four projects can be defined based on the considered case. (ii) Run the model through macro R (i.e. CTRL + R). (ii) Analyze Table OUT1 and change project formulations and corresponding input data. (iii) One can print input data and results by selecting the corresponding tables.

Methodology and assumptions: AWTIBCI only considers an area that is subject to changes due to project implementation. This implies that WITHOUT conditions consider drylands farming only for those areas which will be irri-

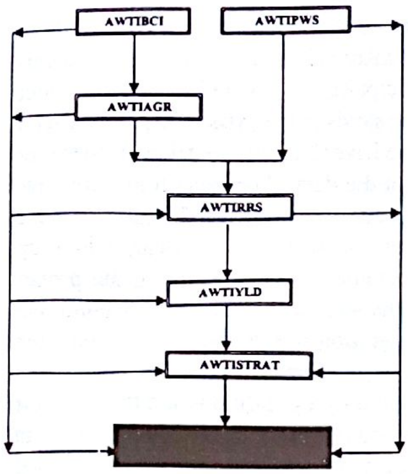

Figure 2. Computational Framework for Analysis

gated through the project. The model does not consider drylands farms that remain drylands farms after project implementation. Consequently results on crop production should not be used as total production from the considered area.

In a set of separate tables, project independent net revenues per ha are computed for selected crops. Drylands farm yields (only summer crops) and input costs are estimated at about 60% of irrigated yields. Cattle refer to goats & sheep: 2 animals per ha on 20% of the area; slaughtering rate 25%. Yields and input costs for irrigated areas are taken from (SOGREAH, 1990), complemented with (FAO, 1979).

Rehabilitation can be partial, expressed through the irrigation efficiencies that can be selected in between minimum and the maximum values, indicated in table 2. The costs of the rehabilitation project and the crop production (and consequently the net revenues) are interpolated between assumed maximum and minimum values, linearly proportional with the irrigation efficiencies. For this purpose table 2 computes a correction coefficient as CF = (IRREFFest - IRREFFmin) / (IRREFFmax - IRREFFmin). Where IRREFF refers to irrigation efficiencies and subscripts to the estimated (est) and minimum (min) and maximum (mix) values.

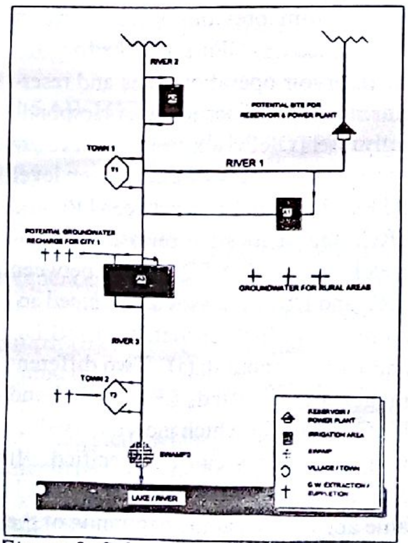

Figure 3. Schematized map of the hypothetical river configuration

2.2 AWTIAGR: model for computation of agricultural water demand

Purpose: AWTIAGR estimates monthly water demands for individual irrigation projects taking into account: (i) a specific cropping pattern and corresponding crop water use coefficients (K_c coefficients); and (ii) specific precipitation and evaporation data. Resulting water demand data provide an input data into the river basin and reservoir simulation model(s).

Model operation: The following steps should be followed to operate the AWTIAGR spreadsheet model. (i) Fill out those input tables that differ for each run: Input data can be found in Table IN1 & Table IN2 from AWTIBCI model. (ii) The K_c coefficient (Table 3) is project independent; usually there is no need to change them, unless for reasons of sensitivity analysis. (iii) The input data for rainfall and evaporation (Table 4) can be changed. (iv) Run the model through macro R (i.e. CTRL + R). No water demand is generated when zeros are found in one of the input tables. The main output is given in Tables 7A, 7B, 7C, 7D and 8. Water demands per crop provide an input data into the AWTIYLD model, and the total water demand provides an input data for the AWTIRRS model. (v) After checking the result Tables 7 and 8, one can print the input & output tables.

Methodology and assumptions: AWTIAGR calculates the crop water requirements based on the procedures presented in FAO publications (FAO, 1974). The formulae, which are developed for semi-arid zones, are used also in the FAO model for crop water assessment (CROPWAT).

2.3 AWTIPWS: model for projection of public water demand

Purpose: AWTIPWS estimates monthly water demands for public water supply for individual urban areas for three different scenarios: average, low and high. These scenarios combine respective estimates of: actual population and population growth factors.

Model operation: The following steps should be followed to operate the AWTIPWS spreadsheet model. (i) Fill out those input tables that differ for each run: Tables 1, 2 and 3. These tables are to be filled with data on the distribution of the urban population, population growth scenarios, % of losses, % of connections and consumption per day, and economic & financial data. (ii) Run the model through macro R (i.e. CTRL + R). (iii) Analyze output data in Table 6 and print input data and results if one wants by selecting the corresponding tables.

Methodology and assumptions: AWTIPWS works based on the standard PWS demand forecasting procedures and the total demand takes into account the losses. Three scenarios (low, average & high) are considered.

2.4 AWTIRRS: model for simulation of river basin and reservoir operation in three representative years

Purpose: AWTIRRS simulates water flows in monthly time steps in a river-reservoir system, matching demand and supply through the operation of reservoir. Through the application of reservoir operating rules a reservoir release is determined as *a function of the water available at the beginning of the month*. Subsequently, water is allocated to the different use categories: irrigation, public water supply (PWS), hydropower and low flow requirements. The model has the following main characteristics, possibilities and limitations. (i) The model is pre-conditioned to the hypothetical river configuration in Fig.1, considering the following components: two rivers, one reservoir with facilities to generate hydropower, four irrigation demand areas, three public water extraction points and one location where low flow conditions can be defined. Customizing the model for other river configurations, (within the limitations of the number of the mentioned components) is relatively easy, requiring reconstruction of the demand and allocation schemes. (ii) Only three representative years can be analyzed (related % to be indicated by users). The model runs the three years sequentially, resetting reservoir levels in the first months of the three years to a specified initial level. This implies that the model does not iterate to match initial and final levels for the individual years. (iii) Four reservoir levels (volumes) can be differentiated in the rule curves: (a) a Flood control level (FRC); (b) an Energy control level (ERC); (c) an Utility control level (URC); and (d) a Dead storage level (DSC). Above FRC, all excess water will be released. In the range FRC - ERC all demands will be allocated. In the ranges ERC - URC and URC - DSC, hydropower and "utility" demands (irrigation, PWS and low flows) can be reduced separately. (iv) The model gives an overview of occurring shortages of allocated water and generated hydropower in terms of expected values, which take into account the % of representativeness of the three selected years. (v) As mentioned, the model allocates water given the situation at the beginning of the month. Only for levels below DSC a correction is made afterwards by *not allowing reservoir levels below DSC*.

Model operation: The following steps should be followed to operate the AWTIRRS spreadsheet model. (i) Fill out the tables with hydrological information, including: Long time series (33 years) for the River 1 & River 2, short time series (3 representative years) for the same rivers, and one year of net-precipitation/evaporation data (hereinafter called evaporation). The long time series are presently not used in the computational procedures. They may serve, however, in the selection of representative years. (ii) Specify data on reservoir infrastructure and operating rules (tables IN4 and IN5). Reservoir data (storage and area curve are preset); Operating rules: FRC, ERC, URC, and DSC levels; Reduction coefficients for allocation to users, corresponding with these four levels: initial reservoir storage, turbine characteristics (installed capacity; elevation of turbine axis), design discharge (maximum turbine flow). (iii) Fill out the table IN2 with irrigation requirements for the specified demand points DIR1 through DIR4. These data are taken from AWTIAGR. (iv) Enter other demand information (table IN3): low flow requirements; hydropower requirements; and PWS surface water requirements. (vi) Set the counters NM1 and NM2 in table IN1 (general run information) to the correct values (table IN1). The model runs for any period in between 1 and 36 months. However, the initial reservoir volume, specified above, will only be preset in the months 1, 13 and 25. (vii) Run macro M (by pressing CTRL + M), which first calls the following menu: *INPUT COMPUTE GRAPHICS QUIT. INPUT*: copies the river discharge and evaporation data as well as the reservoir operating rules and irrigation requirements into the detailed computation table. Through INPUT, user is asked to specify the percentages of representativeness for the selected years, an error message will appear when percentages do not add up to 100. *COMPUTE:* performs the computations and collecting the summary results in tables OUT1 through OUT4 on shortages for irrigation, PWS, hydropower and low flow requirements. Detailed inputs and outputs for each time step are given in a corresponding named table. *GRAPHICS:* shows in sequence four graphs: reservoir operation rule curves, water shortage for the three representative years, energy shortage for the three representative years, and a summary (bars) of expected water shortages for the four user categories. *QUIT:* leaves the menu.

Methodology and assumptions: For each time step (month), the model performs the following computational steps. (i) First, the demand for release of the reservoir is computed from the water demand input data. This is done in a specially designed part of the spreadsheet: river demand scheme. In this scheme, the River 1 is represented with cells, which represent sites of extraction and the River 2 inflow. The computation follows the river from downstream to upstream, adding extractions and subtracting the River 2 inflow (after subtracting the allocated amounts along the River 2 for irrigation area 1 and municipality 3). Monthly data on water demands in the extraction points and on the River 2 runoff are taken from the input the data. For data on irrigation requirements and River 2 flow, which are not constant over the year, a look-up formula is used specifying the proper time step in the year. (ii) Second, the operation of the reservoir is simulated as a function of the release demand, the hydrologic conditions and the reservoir operating rules. This is partly done in macro C, partly in a specially designed "leave" of the spreadsheet called: reservoir operation. The following sequential procedure is applied. (iii) Determine the release as maximum of the requirements for hydropower generation and reservoir release demand (previous step). The hydropower requirement is computed as follows.

$$\text{REQE}=\frac{P_1\times 2630}{0.9\times 9.81\times(\text{H}-\text{H}_t)}$$

Where: REQE = water requirement in Mm³/month, P_1 = firm or primary energy demand in MW, H = water level in reservoir in m, H_t = level of turbine axis in m. REQE is set to the minimum of this value and the design turbine flow, which should be entered as an input data.

(iv) Compute the reservoir volume at the end of each time step as STOR1 = STTOR + RESIN – REL – EVAP. In which STOR1 = storage at end of time step, STOR = storage at beginning of time step, RESIN = River 1 inflow, REL = release from previous step, EVAP = evaporation. STOR1 is checked against the reservoir operation rules and reservoir release is determined correspondingly. If STOR1 is above FRC, the reservoir spills all excess water to keep level at FRC. If STOR1 is in between FRC and ERC, the requested release is completely given. If STOR1 is in between ERC and DSC, releases are reduced according to reduction coefficients REDE and REDU (input data). Two different ranges are specified: ERC - URC and URC - DSC, for which individual reduction coefficients can be specified. If STOR1 is below DSC, the water available above DSC at the beginning of the month is allocated using the reduction coefficient of range URC - DSC. If the volume at the end of the month is still below DSC, the release is set at the difference between the initial level and DSC and STOR1 is set at DSC. Release through the turbine is assessed and generated hydropower is determined, using a formula, similar to the above one to compute REQE. (i) The available, released water is allocated to users as function of the released water and the position downstream of the reservoir. This is done in a specially designed part of the spreadsheet called river allocation scheme, which includes the River 2 and the River 1. Here the computation goes in downstream direction, subtracting extractions and adding the River 2 inflow to the River 1 main flow priority is given to public water supply. For the irrigation areas 3 and 4, shortages are distributed proportionally to the demand. (ii) After completing these computations for the considered time-span, the model computes averages and expected values of water and energy shortages.

Following from above, computations are performed partly through macro C and partly in three "leaves" of the spreadsheet on demand, reservoir operation and allocation. Macro C performs the following functions. (i) It structures the iterative procedure for the time steps to be considered. (ii) It sets the initial value to the reservoir volume in the months 1, 13and 25. (iii) It determines the releases and stored water at the end of the time steps through application of the reservoir operating rules. (iv) It computes the generated hydropower. (v) It writes the results down in the detailed output table.

2.5 AWTIYLD: model for assessment of yield reduction and damages due to water shortages

Purpose: AWTIYLD estimates consequences of water shortages in terms of: (i) the yield reductions for selected crops; (ii) expected financial and economic damages; and (iii) reductions in employment and farmer's income for four selected irrigated areas. Results refer to one specific hydrological condition - for example a 2% dry year of the year 1987 - and only give changes with respect to a situation without damages. Inputs include the water shortages per project computed in the river basin simulation model. Results are passed on to the AWTISTRAT spreadsheet for further financial and economic computations.

Model operation: The following steps should be followed to operate the AWTIYLD spreadsheet model. (i) Fill out those input tables that differ for each run: Tables IN1 & IN2 from AWTIBCI; Table IN5 by hand, using the results of the river basin simulation model (AWTIRRS); and check if general data on crop and soil characteristics remain unchanged. (ii) Run macro R (by pressing CTRL + R). During the execution of this macro detailed water demand tables for individual crops are imported from AWTIAGR. Macro R asks for the name of the AWTIAGR spreadsheet containing the data. Select the output & input tables if you want to print.

Methodology and assumptions: Table 5 presents the computation of the water shortages per crop, per month and per zone. In these tables, the total water deficits are distributed over the different crops, proportional to their contribution to the total water demand in a specific month (Table 4). Table 6 presents the core of the yield reduction computations, in the following steps: (i) the shortages per crop are first converted to shortages at field level by multiplying these shortages with the (weighted) irrigation efficiencies. These computations in table 6 are executed per season. Care has been taken that no double counting occurs because of the system of indicating cropping patterns in table 2, which give crop factors perennial crops in all three columns: summer, winter and year. This correction has been effectuated in table 5, when summing up seasonal and yearly total water deficits. (ii) The total amount of soil water is computed which is available (p*D*Sa). (iii) The root zone deficit is assessed being the shortage at field level minus the available root zone water $p^*D^*S_a$ which is available without ET_a/ET_m being affected. (iv) Et_a/Et_m and Y_a/Y_m are subsequently computed through the formulae:

$$1 - \frac{Y_a}{Y_M} = k_y \times \left(1 - \frac{ET_A}{ET_M}\right)$$

$$\frac{ET_a}{ET_m} = e^{-0.7 * \frac{RS}{(1-p)*D*S_m}}$$

Where: ET_m = maximum plant evapotranspiration equals K_c*ET_o, where K_c is the crop coefficient and ET_o the reference evapotranspiration; ET_a = the actual evapotranspiration; K_y = the yield response factor; Y_a = actual crop yield; Y_m = maximum crop yield; RS = root zone shortage after taking into account the available soil moisture $p^*D^*S_m$; p = proportion of the total available soil water which can be depleted without ET_a becoming smaller than ET_m; D = root depth in m; S_m = maximum available soil water for the plant which equals the depth of water in mm/m of soil depth between the soil water contents at field capacity and at wilting point.

Table 7 gives a summary of the potential and the actual yield of all considered crops. Yield reduction is computed in tons and %. Care has been taken to avoid double counting for damage in seasons and the total year. Table 8 gives final financial and economic estimates. Revenue reduction is estimated by multiplying the yield reduction with corresponding financial or economic prices. Cost reduction is estimated as percentage of the total production costs. The actual version of the model takes as cost reduction half of the yield reduction in percentages (Table 7). Expected damage (last three columns Table 8) can be computed through the following formula, considering a 2%, a 15% and a 50% representative hydrological year:

$$D_e = 0.085^*D_2 + 0.24^*D_{15} + 0.675^*D_{50}$$

here D refers to damage and subscripts to the expected value (e) of the frequency of occurrence of specific hydrological years (here: 2%, 15 % and 50 %). The coefficients are calculated as: the range between 0% and the average of 2 and 15%; the range between the last mentioned average and the average between 15 and 50%; and the range between the last mentioned average and 100 %. S_m values (Table 3) are estimated using the FAO classification (FAO, 1979): Heavy textured soils (200mm/m); Medium textured soils (140mm/m); Course textured soils (60mm/m).

PULATION 2000			
TOTAL	380,000		
TOWN1	56,000		
TOWN2	20,000		
RURAL AREAS	304,000		
VARIATION OF ESTIMATE ACTUAL POPULATION:			20
POPULATION GROWTH	1 - 10 YEARS	11-> YEARS	
AVERAGE SCENARIO	4.9	4.4	% per year
LOW SCENARIO	4.5	4	
HIGH SCENARIO	5.1	4.6	

Table 1: population data - AWTIPWS model

LOSSES			35	%
CITY1 SUPPLY			2	m3/s
CITIES EXTRACTION POINTS (in '000 m3/day)	2000	2010		
TOWN1 SW	2.2	8		
RECHARGE DUNES	0	130		
TOWN2 SW	1	1		
TOWN2 GW	0	2		
CONNECTION RATES	2000	2010	20XX	
STANDPIPE	25	65	75	% of pop.
HOUSE CONNECTION	15	25	35	% of pop.
WELLS RURAL AREA	25	60	75	% of pop.
CONSUMPTION	2000	2010	20XX	
STANDPIPES	40	50	60	lpcpd
HOUSE CONNECTIONS	80	100	120	lpcpd
OFFICES	2	4	5	lpcpd
WELLS RURAL AREA	20	30	40	lpcpd

Table 2: public water supply data - AWTIPWS model

	FIN COST	ECON COST	IMP	DISTRIBUTION EQ	SL	UL
INV. REHABILITATED						
FAMILY FARM	1800	1332	20%	30%	10%	40%
COMMERCIAL FARM	2200	1628	20%	30%	10%	40%
INV. NEWLY IRRIGATED						
FAMILY FARM	2400	1728	20%	20%	12%	48%
COMMERCIAL FARM	3000	2160	20%	20%	12%	48%
MAINTENANCE IRRIGATION WORKS						
NEW: % OF INVESTMENT COSTS	5.00%	3.20%	5%	5%	18%	72%
OLD (US$/ha):	10	6.3	5%	5%	18%	72%

Table 4: total project cost (US$/ha) - AWTIBCI model

	O	N	D	J	F	M	A	M	J	J	A	S
PREC (20%)	44.2	63.8	90.4	125	106.2	84.2	48.5	24.8	17.4	11.1	12.6	24.9
EFF PREC	16.5	28.3	47.3	75	60	42.4	19.1	4.9	0.4	0	0	4.9
EVAP	150.6	156.3	168.3	166.4	134.1	129.2	102.9	81.4	64.4	70.3	94.1	123

Table 4: precipitation and evaporation (mm/month)

2.6 AWTISTRAT: model for Computation of strategies

Purpose: AWTISTRAT supports the formulation of strategies, enabling analysts to place the infrastructural components of a strategy in a proper time frame and calculating the impacts in terms of main indicators. The infrastructure components are the reservoir; four irrigation projects; a hydropower plant; the recharge facilities for the dunes; and the PWS 'connections'. Indicators refer to the economic efficiency; the agricultural production for four selected crops (maize, tomatoes,pineapple and sugar cane); the incremental net revenues for these projects; the costs; and the employment and farmer's income. Results of AWTISTRAT can be used in the pineapple and sugar cane); the incremental net revenues for these projects; the costs; and the employment and farmer's income. Results of AWTISTRAT can be used in the compilation of a scorecard. Care should be taken that the input data represent the differences between situations WITH and WITHOUT a project and not the situation in the future.

Model operation: The following steps should be followed to operate the AWTISTRAT spreadsheet model. (i) Fill out those input tables that differ for each run: Table 3 with data on agricultural projects (by hand). These data are taken from AWTIBCI and AWTIYLD; and make sure general input data – compiled in Table 1 (economic base data) and Table 2 (investment and maintenance costs for reservoir and hydropower) are correct. (ii) Fill Table 4: total investments for the distinguished projects; and distribution of construction activities in the coming 10 years. The distribution of construction activities has to be such that yearly amounts not surpass the budget constraints. To facilitate comparison, column J computes the total yearly cash flow for investments. (iii) Related to the timing of the infrastructure works the distribution of benefits can be established in Table 5 for the irrigation projects, the hydropower plant and the recharge facility. (iv) Fill the economic investment costs in table 6 for the four irrigation projects and the PWS projects, other economic investment costs are calculated in the spreadsheet itself. (v) Fill the incremental maintenance costs (economic) in Table 7. (vi) Fill the incremental yearly benefits (economic analysis) for the four irrigation projects, the hydropower plant and the PWS recharge facilities in Table 8. (vii) In the same Table 8 the expected damages for the four irrigation projects have to be specified (economic analysis). Print input and output data if one want by selecting the corresponding tables

YEAR	AVERAGE TOWN1 (m3/day)	AVERAGE TOWN2 (m3/day)	AVERAGE RURAL (m3/day)	LOW TOWN1 (m3/day)	LOW TOWN2 (m3/day)	LOW RURAL (m3/day)	HIGH TOWN1 (m3/day)	HIGH TOWN2 (m3/day)	HIGH RURAL (m3/day)
2000	2068	738	6080	1654	591	4864	2481	886	7296
2001	2459	878	6697	1960	700	5337	2957	1056	8052
2002	2894	1034	7356	2298	821	5840	3486	1245	8861
2003	3375	1206	8059	2670	953	6374	4074	1455	9727
2004	3907	1395	8809	3078	1099	6941	4724	1687	10652
2005	4493	1605	9608	3526	1259	7541	5443	1944	11640
2006	5136	1834	10457	4015	1434	8176	6234	2226	12692
2007	5841	2086	11358	4549	1625	8847	7103	2537	13813
2008	6611	2361	12315	5129	1832	9555	8055	2877	15005
2009	7452	2661	13329	5760	2057	10302	9097	3249	16272
2010	8367	2988	14402	6442	2301	11089	10234	3655	17615
2011	9130	3261	15537	7003	2501	11917	11189	3996	19040
2012	9953	3555	16744	7605	2716	12793	12220	4364	20553
2013	10840	3871	18027	8251	2947	13721	13335	4762	22176
2014	11795	4213	19390	8943	3194	14702	14538	5192	23899
2015	12824	4580	20839	9686	3459	15740	15836	5656	25733
2016	13931	4975	22377	10482	3743	16837	17236	6156	27686
2017	15121	5400	24011	11334	4048	17997	18744	6694	29764
2018	16401	5857	25745	12246	4374	19223	20370	7275	31975
2019	17776	6349	27585	13222	4722	20518	22120	7900	34326
2020	19253	6876	29537	14265	5095	21885	24004	8573	36825

Table 6: output summary table - AWTIPWS model

CROP	O	N	D	J	F	M	A	M	J	J	A	S
			FIRST SEASON						SECOND SEASON			
WITHOUT PROJECTS												
OBJECT AREA1	05	1	13	09	04	02	04	09	07	03	01	0
OBJECT AREA2	55	101	126	85	4	18	46	93	78	44	12	07
OBJECT AREA3	16	31	39	26	12	05	12	26	21	1	02	0
OBJECT AREA4	06	12	16	1	05	02	05	1	08	04	01	0
WITH PROJECTS												
OBJECT AREA1	26	51	64	43	2	07	2	42	34	17	04	0
OBJECT AREA2	92	174	218	147	69	29	75	148	132	81	29	07
OBJECT AREA3	107	206	261	174	8	3	8	172	139	69	14	0
OBJECT AREA4	13	42	81	8	5	07	21	35	42	39	09	0

Table 8: overview of total water demand (Mm3/month) - AWTIAGR model

Name of project / Areas & efficiencies		Project 1: River 1 Without Area (ha)	Without Eff. (%)	With Area (ha)	With Eff. (%)	Project 2: River 3 LB Without Area (ha)	Without Eff. (%)	With Area (ha)	With Eff. (%)	Project 3: River 3 RB Without Area (ha)	Without Eff. (%)	With Area (ha)	With Eff. (%)	Project 4: River 2 Without Area (ha)	Without Eff. (%)	With Area (ha)	With Eff. (%)
Act. Irrig/rehabilitated	FF	500	0.4	500	0.7	4760	0.4	4760	0.7	1500	0.4	1500	0.7	600	0.4	600	0.7
	CF					1240	0.6	1240	0.7								
drylands/newly irrigated	FF			990	0.6			2520	0.6			4155	0.6			4400	0.6
	CF			2310	0.7			5850	0.7			9695	0.7				

Table IN1: project data- AWTIBCI model

CROP	WITHOUT SUMR	WITHOUT WINTR	WITHOUT YEAR	PROJECT 1: RIVER 1 SUMR	WINTR	YEAR	PROJECT 2: RIVER 3 LB SUMR	WINTR	YEAR	PROJECT 3: RIVER 3 RB SUMR	WINTR	YEAR	PROJECT 4: RIVER 2 SUMR	WINTR	YEAR
Family Farms (FF)															
MAIZE (winter		0.30			0.30			0.30			0.30			0.30	
MAIZE (summer	0.20			0.20			0.20			0.20			0.20		
GROUNDNUTS	0.15			0.15			0.15			0.15			0.15		
BEANS (winter)		0.50			0.50			0.30			0.30			0.30	
BEANS (summer)	0.10			0.10			0.10			0.10			0.10		
TOMATOES (winter)		0.10			0.10			0.30			0.30			0.30	
TOMATOES (summer)	0.20			0.20			0.20			0.20			0.20		
ONIONS	0.20			0.20			0.20			0.20			0.20		
CHILIES	0.05			0.05			0.05			0.05			0.05		
SWEET POTATOES	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Commercial Farms (CF)															
MAIZE (winter		0.20			0.20			0.20			0.20				
MAIZE (summer	0.20			0.20			0.20			0.20					
SUNFLOWER	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10			
BEANS															
TOMATOES (winter)		0.20			0.20			0.20			0.20				
TOMATOES (summer)	0.30			0.30			0.30			0.30					
PINEAPPLE	0.10	0.10	0.10	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20			
ALFALFA		0.10			0.10			0.10			0.10				
SUGAR CANE	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20			
SOYBEANS	0.10	0.10	0.10												
TOTAL FF	1.00	1.00	0.10	1.00	1.00	0.10	1.00	1.00	0.10	1.00	1.00	0.10	1.00	1.00	0.10
TOTAL CF	1.00	1.00	0.50	1.00	1.00	0.50	1.00	1.00	0.50	1.00	1.00	0.50	0.00	0.00	0.00

Table IN2: cropping patterns newly irrigated and rehabilitated areas- AWTIBCI model

3.Conclusion And Recommendations

The developed computational framework for analysis (AWTIBCI, AWTIAGR, AWTIPWS, AWTIRRS, AWTIYLD, and AWTISTRAT) will contribute to the consideration of the concept of Integrated Water Resources Management (IWRM) in planning water resources development projects in Ethiopia. According to Hall et al., 1993, integrated water resources management takes full account of: (a) all natural aspects of the water resources system (surface water, groundwater, water quality, physical and chemical behavior); (b) all sectors of the national economy depending on water; (c) the relevant national objectives and constraints; (d) the institutional setting; and (e) the spatial and temporal variation of resources and demands (upstream-downstream interaction, basin-wide analysis, inter-basin and international aspects).

However, the models are not meant to fit every river network configuration and planning conditions. The performance of the models for the considered river network is satisfactory but they need to be further improved. This is because the computational procedures are based on the spreadsheet functions and are transparent to the users. The

	YEAR1	YEAR2	YEAR3	YEAR4	YEAR5	YEAR6
PROJECT 1						
INVESTMENTS	30.00%	25.00%	25.00%	10.00%	10.00%	
MAINTENANCE	5.00%	20.00%	30.00%	50.00%	60.00%	80.00%
BENEFITS	20.00%	20.00%	35.00%	45.00%	55.00%	75.00%
PROJECT 2						
INVESTMENTS	30.00%	30.00%	25.00%	10.00%	10.00%	
MAINTENANCE	5.00%	20.00%	30.00%	50.00%	60.00%	80.00%
BENEFITS	10.00%	20.00%	35.00%	45.00%	55.00%	75.00%
PROJECT 3						
INVESTMENTS	30.00%	25.00%	25.00%	10.00%	10.00%	
MAINTENANCE	5.00%	20.00%	30.00%	50.00%	60.00%	80.00%
BENEFITS	10.00%	20.00%	35.00%	45.00%	55.00%	75.00%
PROJECT 4						
INVESTMENTS	60.00%	25.00%	15.00%			
MAINTENANCE	5.00%	20.00%	35.00%	45.00%	60.00%	70.00%
BENEFITS		30.00%	35.00%	45.00%	55.00%	65.00%

TABLE IN3: time scheme of costs and benefits- AWTIBCI model

MONTH	FRC	ERC	URC	DSC
1	805.4	630	167.2	122.459
2	805.4	650	150.9	122.459
3	805.4	660	143.3	122.459
4	805.4	620	156.7	122.459
5	805.4	640	168.5	122.459
6	805.4	650	164.6	122.459
7	805.4	670	157.3	122.459
8	805.4	680	144.5	122.459
9	805.4	670	141.5	122.459
10	805.4	660	153.1	122.459
11	805.4	650	166	122.459
12	805.4	660	174.8	122.459

Table IN4: reservoir operating rules (Mm3) - AWTIRRS model

	shortages in percentage of demand	
PWS	0	0
IRR	0	0
HP	0	0
LF	0	11

Table OUT6 summary of outputs - AWTIRRS model

INITIAL RESERVOIR STORAGE				
250	Mm3			
REDUCTIONS IF BELOW RULE CURVE LEVEL				
	FRC	ERC	URC	DSC
HYDRO	0	0.2	0.8	1
UTIL	0	0	0.2	1
RESERVOIR HELP FUNCTION				
LEVEL	VOL			
97	200.939			

Table IN5: other reservoir data - AWTIRRS model

base line data used is also real data from the Incomati River Basin.

Whenever possible, especially for underdeveloped countries like Ethiopia, it is better for planners to develop easy and flexible spreadsheet models rather than expensive and sophisticated commercial software. While attempting to model the system, planners will enhance their understanding of the problems and may find possible alternative solutions. Spreadsheet models are relatively easy to understand and can also be easily modified for other conditions.

In fact for each of the above programs there are several commercial software. But most commercial software do not exactly fit with one's specific problem. Therefore, the primary objective of this research project is to disseminate the use of spreadsheet macro-programming in planning sustainable WRD projects in Ethiopia. Based on which, planners will be able to understand the physics of the analysis. However, if one uses commercial software, then one may not be able to fully understand the physics of the analysis.

The applications of the computational framework for analysis are fourfold:

1) It has already become a computational module for the Water Resources partments' final year students in AWTI. In the long-term, AWTI graduManagement course for the final year Hydraulic & Irrigation Engineering Deates will disseminate the system in Ethiopia;

2) Professionals in the SAERP (SAERT, SAERAR, SAERSAR, etc.) and other organizations could start practicing similar methodology;

3) The concept of IWRM could be disseminated in Ethiopia through the use of such appropriate computational tools;

4) Introduction of such a computational tool will contribute to Ethiopia's capacity building in the water sector and thus has a direct socio-economic benefit.

It is recommended that the models be improved further and updated regularly. An interface program could be written to operate the models as menu-driven. Further improvement to fit them for different river networks will ultimately lead to software establishment.

NM1	1		MONTH	1	# of month in one year
NM2	36		NY	3	# of years (computed)
NM	36		FY	1935	First year (LTS)
YR	4	actual year	LY	1937	Last year (LTS)
			INTYR	1933	Initial year
CNT	37				
CT	4	counter subroutines 2 and 3			
CNT1	5	counter irrigation areas			
CNT2	13	counter months (total series)			
POINT	36	counter for filling output tables			
ITER	50	required difference between two iterations			
PERCENTAGES REPRESENTATIVE YEARS (input through macro)					
51		% first year		1942	
20		% second year		1947	
29		% third year		1964	
100		% Total			

Table IN1: general run information - AWTIRRS model

IRR	18
B/C RATIO	2.6
N/K RATIO	7.8
INVESTMENT COSTS (M$), FINANCIAL	
RESERVOIR	11.2
HYDRO POWER	6.5
AGRICULTURE	26.2
PWS	0.2

Table 10 Summary of results - AWTISTRAT model

	PROJECT1		PROJECT2		PROJECT3		PROJECT4	
ECONOMIC INDICATORS								
NPV (M$)		0.1		0.4		0.6		0.1
IRR (%)		49		37		46		33
B/C RATIO		2.8		2.4		2.9		2.5
N/K RATIO		7.8		5		7.2		3.9
INCREMENTAL NET REVENUES ('000 $)	FIN	ECON	FIN	ECON	FIN	ECON	FIN	ECON
WITHOUT PROJECT		2166		12174		8280		2798
WITH PROJECT		7013		27068		29051		8533
INCREMENTAL		4847		14893		20770		5735
COSTS ('000 $)								
INVESTMENT COSTS	10206	7366	33620	24405	41757	30119	11640	8402
MAINTENANCE COST WITHOUT	5	3	60	38	15	9	6	4
MAINTENANCE COST WITH	510	321	1749	1102	2088	1315	582	367
INCREMENTAL MAINTENANCE COSTS	505	318	1689	1064	2073	1306	576	363
AGRICULTURAL PRODUCTION ('000 tons)	WITHOUT	WITH	WITHOUT	WITH	WITHOUT	WITH	WITHOUT	WITH
MAIZE	2.5	5.6	12.4	28.6	9.9	22.6	3.3	7.5
TOMATOES	10.6	24.7	47.6	104.6	42.4	114	13.9	31.1
PINEAPPLE	0	6.7	1.6	20.5	0	27.9	0	0
SUGAR CANE	0	3.5	1.7	10.9	0	14.8	0	0
EMPLOYMENT (man years)	1271	1228	4997	5612	5070	5061	1666	2820
FARMERS INCOME ('000 $)	3326	3534	14803	18011	12904	14366	4317	11104

Table OUT1 summary of outputs - AWTIBCI model

Table OUT1 summary of outputs -

NM1	1		MONTH	1	# of month in one year
NM2	36		NY	3	# of years (computed)
NM	36		FY	1935	First year (LTS)
YR	4	actual year	LY	1937	Last year (LTS)
			INITYR	1933	Initial year
CNT	37				
CT	4	counter subroutines 2 and 3			
CNT1	5	counter irrigation areas			
CNT2	13	counter months (total series)			
POINT	36	counter for filling output tables			
ITER	50	required difference between two iterations			
PERCENTAGES REPRESENTATIVE YEARS (input through macro)					
51		% first year		1942	
20		% second year		1947	
29		% third year		1964	
100		% Total			

Table IN1: General information - AWTIRRS model

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Moisture Regimes of Ethiopia

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Abstract

The majority of Ethiopia's population depends on rainfed agriculture for their subsistence. However, the crop production in the country is affected by the vagaries of weather and climate. Hence, it is very important to identify homogenous zones in relation to the agroclimatic resources available. For this purpose, Thornthwaite's (1948) approach to classify the moisture regimes as modified by Reddy (1977) is adapted in this study.

The results of this study indicate that four moisture regimes are identified in the country. These are humid, sub humid, semi-arid and arid zones. The sub humid and semi arid zones are further subdivided into wet & dry sub humid and wet and dry semi arid zones respectively. The national map of moisture regimes is drawn based on this study. It is found that 6.4%, 25.8%, 28.3% and 38.8% of the country is under humid, sub humid, semi arid and arid moisture zones respectively.

The agroclimatic potential of each of the zones is discussed in relation with the mean annual rainfall and PET distributions and the relative biomass productivity (Williams, 1985). As a result of this the humid zone is found to be more productive if water and land are properly managed. On the other hand, the arid zone covers larger area of the country and unsuitable for rainfed agriculture.

Key Words: Arid, humid, semi arid, sub humid

Introduction

The economy of Ethiopia greatly depends on rainfed agriculture, which is influenced by climatic and topographical diversities. Inventorying the agroclimatic resource can assess the agricultural potential of a given location. If we are successful in identifying the agroclimatic resource it will help us to understand the constraints for crop production. Moreover, agricultural planning and drought monitoring could be enhanced. Hence, to manage the climatic and topographic differences of the country, one has to identify regions and classify them in homogenous zones. Agroclimatic classification technique helps in grouping homogenous zones together. Since there is no temperature limitations in Ethiopia, a classifying method that is based on rainfall and PET is chosen to identify the moisture regimes of the country. The identification of regions can be made using agro-climatic classification.

The main objective of this study is to classify the country into different moisture regimes. Lemma (1996) has carried out climatic classification of Ethiopia. However, his classification is mainly based on temperature limitations and the result is useful for the general purpose. On the other hand, this study allows more refined analysis related to vegetation based on the effectiveness of rainfall.

Each of the homogenous zones is discussed based on the annual rainfall and PET distributions and the climatic index of agricultural potential. The result of this study is believed to assist planners, environmentalists, agriculturists, researchers and so on.

The mean annual rainfall and PET discussion is based on the works of Engida (1999) and NMSA (1996). The climatic index of agricultural potential (CA) discussion, which explains the relative biomass productivity, is based on the works of Williams (1985).

For the identification of the moisture regimes, Thornthwaite's approach as modified by Reddy was adopted in this study.

Materials And Methods

Data set

For the moisture regime classification of the country, mean annual total rainfall (R) and mean annual potential evapotranspiration (PET) data for some 381 stations were used. These stations are well distributed all over the country. However, the data set used in the study does not represent the same and long period.

Methodology

The literature is rich in papers that deal with climatic classification. The majority of existing classifications use two primary factors to define climate; namely moisture that limits plant growth and evaporative demand that expresses the moisture need at a place for optimum plant growth (Reddy, 1983).

Most of the procedures that are in wider use are annual indices (Köopen 1936, Thornthwaite 1948, Thornthwaite & Mather 1955, Budyko 1956, Papadakis 1975 and so on). While the procedures that use the moist or dry period are more common for the sub division of semi arid zones (Cocheme & Franquin 1967, Brown & Cocheme 1969, Raman & Murthy 1971), with few exceptions that are used to demarcate semi arid zones.

There are no temperature limitations in tropics. Hence, as Ethiopia is found in tropics, modified Thornthwaite's method is adopted in the study. Thornthwaite's (1948) moisture regimes classification introduces the most important term potential evapotranspiration and degree of moisture of climatic units by means of an estimate of soil water balance. Thornthwaite & Mather (1955) subsequently modified the latter. On the other hand, the main emphasis of Köopen's classification is on temperature limits. Thornthwaite's climatic classes are based on the effectiveness of rainfall. This factor bears a close relation to plant growth and hence permits more refined analysis of climatic problems related to vegetation and agriculture than does Köopen's scheme (Berry et al 1973). In the Thornthwaite's approach, while dividing the zones different arbitrary chosen intervals were used in the division of humid and dry areas. These limits aren't homogeneous with respect to crop production areas.

Reddy (1977) suggested some modifications to Thornthwaite's scheme to develop more homogeneous types. The soil term was eliminated in the computation of moisture index. The same weights were given both for humid and arid indices; and uniform limits were used on both humid and arid sides of the scale. According to the Modified Thornthwaite's approach, the main formula adopted is indicated below and the classification is based on Table 1.

$$Im, \% = \frac{(R - PET) * 100}{PET}$$

Where Im - moisture index, in %

R - mean annual total rainfall, mm

PE - mean annual total potential evapotranspiration, mm

Moisture regime	Symbol	Im (%) limits
Arid	A	Im ≤ -75
Semi arid	SA	-75 < Im ≤ -25
Dry semi arid	DSA	-75 < Im ≤ -50
Wet semi arid	WSA	-50 < Im ≤ -25
Sub humid	SH	-25 < Im ≤ 25
Dry sub humid	DSH	-25 < Im ≤ 0
Wet sub humid	WSH	0 < Im ≤ 25
Humid	H	Im > 25

Table 1. Criteria used to classify the moisture regimes (Reddy,1977).

Results And Discussion

The result of moisture regime classification of the country is presented in Figure 1 taking into account annual rainfall pattern (Engida, 1999;NMSA, 1996) and relief and its aspects (EMA, 1981). Four moisture regimes and four sub zones are identified. These are humid, sub humid, semi arid and arid zones. The sub humid and semi arid zones are further subdivided into wet and dry sub zones. The percentage area coverage of each zone and sub zone is given in Table 2.

Before attempting to discuss the moisture zones it is very important to understand the rainfall climatology of Ethiopia. Hence, based on the monthly and annual rainfall distribution, four rainfall regimes are identified in Ethiopia (NMSA, 1996).

The first rainfall regime is identified by mono-modal rainfall pattern is dominated by single maxima rainfall pattern. However, the wet periods decrease northwards. This region is sub-divided into three parts. Over the first monomodal rainfall regime, which is designated as b1, the wet period runs from February/March to October/November. This regime covers Illubabor and Jimma zones of Oromiya; and Kefa-Sheka, Bench-Maji, Yem, parts of north Omo and parts of Hadiya zones of SNNP. Over the second monomodal regime (b2), the wet season extends from April/May to October/November. This regime covers Benshangul-Gumuz, Gambella; east and west Wellega and west Shoa zones of Oromiya; east and west Gojam, Awi and north Gonder of the Amhara region. Over the third monomodal regime (b3) the wet period runs from June/July to August/September. This subgroup includes south Gonder and eastern parts of the Amhara region and west and central zones of the Tigrai region. Therefore, it is possible to conclude that the western half of the country is characterized by monomodal rainfall pattern.

The second rainfall regime identified as bimodal type 1 rainfall is characterized by quasi-double maxima rainfall pattern, with a small peak in April and maximum peak in August. Therefore, the region is dominated by semi-bimodal rainfall pattern. The type 1 bimodal rainfall pattern covers east and south zones of Tigrai; Wag Hamra, north and south Wello, and north Shoa zones of the Amhara region; Arsi, northern parts of Bale, east and west Hararghie, east Shoa, north west Shoa and parts of West Shoa zones of Oromiya; Sidamma, Gedio, Guraghie and KAT zones of SNNPR; Shinile and Jijiga zones of Somali region. The third rainfall regime, which is identified as bimodal type 2, is dominated by double maxima rainfall pattern with peaks during April and October. Generally, the annual rainfall decreases from west to east. The bimodal type 2 rainfall pattern is usually observed over Borena and southern parts of Bale zones of Oromiya; Konso, Derashe, parts of Bench Maji, southern parts of north Omo and south Omo zones of SNNP; and Liben, Afder, Gode, Kebri Dahar, Fik, Warder and Deghabur zones of Somali region. The fourth rainfall regime is characterized by irregular rainfall pattern and is located over the northeastern parts of the country. Though erratic rainfall prevails from August/September to January/February, the region does not have well defined rainfall pattern. The diffused rainfall pattern is observed over the eastern parts of Afar.

Area	Moisture regimes						Lakes	Total
	Arid	Semi arid		Sub humid		Humid		
		DSA	WSA	DSH	WSH			
in %	38.8	10.5	18.3	15.4	9.9	6.4	0.7	100
in '000 KM²	428.5	116.2	201.6	171.1	108.8	70.9	7.3	1104

Table 2 - Area coverage of moisture regimes of Ethiopia

Humid Zone

The humid zone is found over the Western parts of the country and on the highlands of Sidamo, Bale, Arsi, around Chagni (Gojam) and Dabat (Gonder). The zone covers about 6.4 % of the total area of the country, which is about 70,870.2 sq.km. The altitude of the zone is above 2,500 m. above mean sea level. The mean annual rainfall distribution indicates that, over western parts of Ethiopia it varies between 1800 and above 2200 mm. Over the Sidammo Bale highlands the rainfall amount is between 1600-2000 mm. The humid zones of northwestern Ethiopia receive mean annual rainfall amount that varies from 1400 to 1800 mm. There is no significant annual rainfall variation over these places.

The mean annual PET distribution over the humid zones of western Ethiopia and the highlands of Sidammo and Bale ranges from 1200-1400 mm. On the other hand, over northwestern Ethiopia it varies from 1400 to 1500 mm.

The climatic index of agricultural potential (CA) of the zone is more than 50 units. CA is considered to be more proportional to the potential biomass productivity as related to climate, and a unit of CA is equal to 0.6 tones of dry matter per hectare [DM/hectare] (Williams, 1985). Hence the potential productivity of the zone is 30 tones of DM/hectare.

Sub humid zone

It is found adjacent to the humid zone and cover more area than the former. It covers about 25.3% (279,819.1

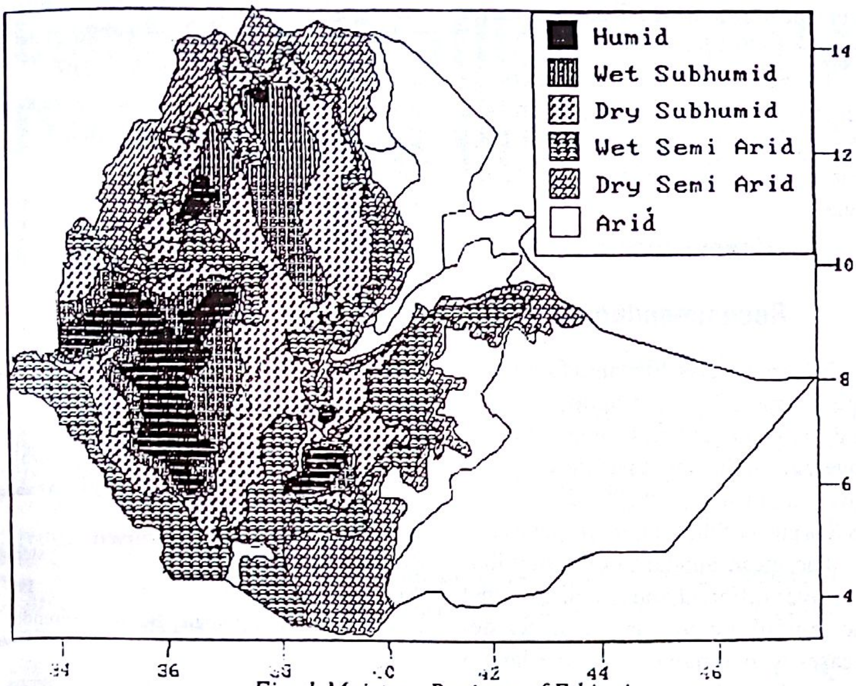

Fig. 1 Moisture Regimes of Ethiopia

km²) of the total area of the country. This zone is further subdivided into Wet sub humid and dry sub humid zones.

Wet sub humid zone (WSH)

The WSH is found adjacent to the humid zone and is located over parts of north and south Gonder and east Gojam, parts of east and west Wellega, Illubabor and Jimma zones and northwestern parts of SNNPR. Moreover, it is found over some pocket areas of the Sidammo Bale highlands.

Part of sub zone, which is found over the western half of the country, is under monomodal rainfall pattern. On the other hand, part of the sub zone over the Sidammo Bale highland is under bimodal type 1-rainfall regimes. The mean annual rainfall distribution indicates that over western Ethiopia it ranges from 1400-1800 mm, over northwestern Ethiopia it varies between 1200-1600 and over the Sidammo Bale highlands it is found to be between 1400-1600 mm. The rainfall distribution all over the WSH is stable and there is no variability.

The mean annual PET varies between 1400 and 1700 mm. As a result, over part of the sub zone, which is found over western Ethiopia, PET varies between 1400-1500 mm. Over the Sidammo Bale highland and parts of the sub zone which is found over northwestern Ethiopia, the PET distribution varies from 1500-1600 and 1500-1700 mm respectively.

The climatic index of agricultural potential indicates that, the western and northwestern Ethiopia parts of the sub zone have CA values ranging from 40-50 and 20-30 units respectively. The WSH sub zone of the Sidammo Bale highlands has CA values between 30-40 units. Most parts of the sub zone are highly productive.

It is located to the left side of the Rift Valley with few exceptions at the highlands of Arsi, Bale and Sidama. The sub zone covers about 108,794.1 sq.km. (9.9 %). The altitude of the sub zone is found between 2500 - 3500 m. above mean sea level.

Dry sub humid zone (DSH)

The Dry sub humid zone is found adjacent to the semi arid zone and covers 15.4% of the total area of the country, which is about 171,066 km². The mean annual rainfall distribution varies between 1200-1400 mm. However, part of the sub zone, which is found northeastern Ethiopia, receives 600-1200 mm of annual rainfall. With the exception of the sub zone over western Ethiopia, the rainfall distribution shows a significant variation.

Parts of the sub zone over western Ethiopia have mean annual PET between 1500-1600 mm. Over the Sidammo Bale highlands, the PET value varies between 1600-1700 mm. Over the other parts of the sub zone the PET amount varies between 1700-2000 mm.

With the exception of parts of Bale and Sidamo during their second rainy season, in the other parts planting hazard is low. In Bale and Sidamo, the second season planting risk is high.

The climatic index of agricultural potential is 40-50 units over western Ethiopia and is between 30-40 units over the Sidammo Bale highlands. It is between 20-30 units over northwestern Ethiopia and between 10-20 units over part of the sub zone in northeastern Ethiopia.

Semi-arid zones (SA)

The semi arid zone covers most parts of the country as compared to the humid and sub humid zones. It covers 28.8 % of the total area of the country to the right and left of the Rift Valley. It has an area of about 342,132 sq. Km. The Semi-arid zone is further subdivided into Dry semi-arid sub zones.

Wet semi arid zone (WSA)

This Sub zone is to the side of Dry Sub humid zone with the area of 201,613.5 sq. km, which are about 18.3 % of the total area of the country.

The highest mean annual rainfall distribution is found over part of the sub zone that is found in northwestern Ethiopia. The amount received over this part of the sub zone is between 1000-1200 mm. The second highest value over the sub zone is over western Ethiopia with the amount varying from 800-1200. The Sidammo Bale highland part of the sub zone receives annual rainfall amount ranging from 600-1200 mm. Over the northeastern part of the sub zone, the mean annual rainfall amount varies from 400 to 800 mm. There is high variability in the mean annual rainfall distribution all over the sub zone with the exception of western Ethiopia.

The mean annual PET distribution over parts of the sub zone ranges from 1500-1600, 1500-1700, 1700-2200 and 1700-2200 mm over western Ethiopia, the Sidammo Bale highlands, the northeastern and northwestern parts of the sub zone respectively.

The climatic index of agricultural potential over the western Ethiopia parts of the sub zone is between 30-40 units and is between 20-30 units over the Sidammo Bale highland and northwestern Ethiopia. However, over northeastern Ethiopia this value is minimal and varies between 1-10 CA units.

Dry semi arid zone (DSA)

The dry semi-arid zone is located adjacent to the arid zone and covers an area of about 115920 km², which are about 10.5% of the total area of the country. It is mainly located over southern lowlands, northeastern and northwestern lowlands of the country.

The northwestern parts of the sub zone receive mean annual rainfall that varies from 600-1000 mm. The southern lowlands of the country receives 400-800 mm of mean annual rainfall while the northeastern lowlands receive mean annual rainfall ranging from 400-600 mm. On the other hand, the lowest mean annual rainfall distribution over the sub zone is found in eastern Tigrai. The amount varies from 200-400 mm. Over most parts of the sub zone, the annual rainfall distribution shows highest variation.

The mean annual PET over northeastern and northwestern lowlands is the highest in the sub zone and varies from 2000-2200 mm. It ranges from 1700-2000mm over Tigrai and is between 1500-1700 mm over southern lowlands.

The climatic index of agricultural potential over most parts of the sub zone is below 10 CA units. However, over northwestern Ethiopia, this value varies between 10-20 CA units.

Arid zone (A)

The arid zone is located in the southeastern and northeastern lowlands of the country. It covers about 39% of the total area of the country, which is about 428,500 sq. km.

The arid zone is found under bimodal types 1 & 2 and diffused rainfall regimes. Generally the arid zone is characterized by low rainfall amount with high variability. The mean annual rainfall distribution of southeastern and northeastern lowlands is below 400 mm and varies between 600-800 mm over the south OMO part of the zone. There is high rainfall variability over most parts of the zone with the exception of south Omo.

The mean annual PET is above 2200 mm throughout the arid zone. However, over south Omo the PET amount varies between 1500-1700 mm.

The value of the climatic index of agricultural potential varies between 1-10 units over south Omo and is below 1 CA unit over the remaining parts of the zone.

Conclusions and Recommendations

Ethiopia is classified into four moisture regimes. They are humid, sub humid, semi arid and arid zones. The area coverage indicates that these zones cover about 6.4%, 25.3%, 25.8% and 38.8% parts of the country respectively.

The mean annual rainfall distribution over different zones indicates that the rainfall amount progressively decreases as one moves from the humid zone to the arid zone. The reverse is true for the PET distribution. The highest PET amount is found over the arid zones and the lowest PET amount is over the humid zone.

The climatic index of agricultural potential (CA) follows the rainfall trend. The humid zone that receives the highest rainfall amount relative to the other zones is characterized by the highest relative biomass productivity. On the other hand, the arid zone is found to be less productive. Area with low CA values implies that the climatic resources would not naturally support agriculture. On the other hand, areas with high CA values are identified as the most productive for agriculture. Turc and Lecerf (1972) suggested that potential productivity is about 0.6 tons/hectare per unit of CA. Hence, the potential productivity of the humid zone is about 36 tons/hectare and it is below 0.6 tons of dry matter/hectare over the arid zone.

The area coverage under arid and semi arid zones is substantial. It covers about 65% of the country. This is a good indication that there is a desertification threat in the country. Hence appropriate measures should be taken to aver the risk of desertification.

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Land Use Conflict in Water Resource Development the Experience in Oromyia Region

Teshome Afrassa

Abstract

The paper examines the distribution of land use and land cover at different point of time (1966/67 and 1974) and identifies the rate of changes in Hare watershed, south Rift Valley of Ethiopia. Moreover, it characterizes the watershed and examines the impacts of land use patterns on the watershed management.

The study is based on interpretation and analysis of aerial photos of different periods. Semi-structured questionnaires, group discussion and silent survey have also conducted.

Forest land, woodland, bush land shrub land and grass land declined by 68%,87%,80%171% respectively in 1974 compared to 1966/67. During the same period of time on the other-hand cultivated land and other (barren land, and swamp land) increased by 18 & 59 percents respectively.

The watershed is severely affected by soil degradation, silitation , flooding and water logging problem. As the land use patterns indicates, the deforestation rate is very high and the yield of the area is declining even in good rain fall period. The major cause of these problems is the unwise use of land resources.

Therefore measured should be taken in accordance with the problems that correct overgrazing deforestation, inappropriate agricultural system and the low level of conservation measures.

1.Introduction

Our basic needs of food and fuel, water , shelter and clothing are met from the land , which is naturally in limited supply. These are achieved by development of land resources. Development brings change in land use and the change brings conflict. As population and aspirations increase, land becomes an increasingly scarce resource.

Land use is the way the land is being used. Land use planning is the systematic assessment of land and water potential and the complex interaction between bio physical potential of the land and, the socio-economic condition of the land users, the institutional and policy environment , in order to select and adopt the best and sustainable land use options.

Land use planning could be done at various level i.e. national, regional, zonal, wereda, peasant association, village and at farm level. Alternatively it can be prepared in river basin, sub - basin and down wards the smallest water shed. Land use planning in water resource development in general and irrigation in particular need to be done at large scale with participation of beneficiaries and stalk holders. Failure to achieve the scale and accomodate interest of the users would develop land use conflict and hampers sustainable water resource developments.

Identification and analysis of land use conflict is over looked in development projects in general and water resource development in particular. Unregreatable disastrous consequences were recorded in1991, where several development schemes demolished by conflicted land user group.

Land use planning of Oromia is conducted as part of contractual assignment given to Metaferia consulting engineers by the regional government to make water resource base line survey and prepare development plan. Land use conflicts were recognized and evaluated in the course of the study.

2.Objective Of The study

The objective of the land use study of the Region is to provide guide lines and decisions on land use and management in water resource planning and development of the region.

The specific objectives of this study is to identify land use conflicts and analyze the effect on sustainable water resource development.

More over it is intended to create an awareness of land use conflict and its effect in water resource planning and development and initiate further works to fill the gaps.

3. Methodology Of The Study

Previous land use planning studies were reviewed and data were compiled. Preliminary analysis and delineation of relatively homogenous land use/land cover types were made on 1:250.000 scale map. A questionnaires and check lists were prepared for beneficiaries and stalk holders to identify and evaluate land use conflicts.

Extensive field survey were conducted in all zones of the region to describe land use types and identify land use conflicts. The statistical (geostatistics or biometric) methods were hardly fit to manpulate the complex dat input in analysis of land use conflicts. To fill the gap, analysis of the result were done subjectively to indicate the level of land use conflict in water resource development. Subsequently land use conflicts in water shed management, existing and planned water resource developments were identified and evaluated. Besides, land use conflict in other developments were investigated to enable planners and decision makers get an overview of the holistic system

4. Description Of Land Use Types in Water Resource Planning.

The are of the Region is estimated to be 356,770 km²

The land use/ land cover pattern of the region are identified and described as follow

Urban/Settlement area: These include cities, towns, villages, industrial and major settlements. Oromia has over 2,000 towns and several more settlements. Their land cover area is expanding progressively. Annual time series data of Oromia Bureau of Works and Urban development data base have to be referred to get updated informations. The interest of water resource planning and management with respect to this land use type is that, the data base will help in planning and designing water supply and sanitation system for municipal and industrial consumption.

Cultivated land: Overall, the actual area mapped as cultivated is about 8.6 million ha. However, significant areas are occupied by settlements, infrastructures, fallow land, interspersed bush and shrub lands. Hence it is estimated that only about half the land mapped as cultivated is actually cultivated. This figure is comparable with the recent cultivated area of the region (obtained from bureau of Agriculture) which is about 5.3 million ha. The interest of water resource planning and management with respect to this land use type is that , the clear designation will help in identification, design and management of small scale , medium and large scale irrigation including the type of crop to be grown for cash and consumption.

Alpine and Afro - alpine: Alpine and Afro - alpine vegetation areas are temperate deserts. They have continuos and high moisture area and the type of species of fauna and flora are limited. These areas are found in altitude > 3200 masl such as Bale- Batu and Arsi - Chilalo, Harerghe-Gara mulata mountains. Its importance in water resource planning and management is sustaining water shed system as they are source of several rivers and streams. For example Bale and Arsi mountains alpine are head water of Dumal, Welmel, Weyib, and other rivers draining to Genale Dawa and Wabishebele rivers.

Forest: Forest is defined as a multi storied tree vegetation complex. Most of the forest area occurs between 1500 - 3000 masl. The countries major forest is found in Oromia. Forest areas in the region are found in west: Jimma, Illubabor, west Wellega and south: Bale, Borena. Total area mapped as high forest is about 3.4 million ha. The figure is comparable with the data obtained from Oromia forestry action plan study, which is about 2.9 million ha. The interest of water resource planning and management is hydro-forestry, sustaining and maintenance of water shed's ecosystem and conservation of the natural ecology.

Wood land: Wood land is considered as a single story tree cover, generally underlain by grass. It is dominated by comberetum spp, a tall grass of hyperrinea spp. It is associated with bamboo and disturbed forest in the west and bush or shrubs in southern and eastern Oromia. Significant potential irrigable areas are found with in wood land. This land cover type occupies 1.3 million ha.

Riparian wood land or bush land: These are a Riverine vegetation growing along the river channels and flood courses. Generally it is distinguished by a greater luxuriance of vegetation, including varieties of species and denser than found in surrounding areas. However, it is highly localized and generally in long narrow strips difficult to separate at this scale of mapping. This is important land use type in river basin planning and management since it occupies the wet lands ,flood plains. More over the vegetation contributes to maintaining the natural channels by avoiding bank erosion. In low lands flood recession cultivation is a common practice. These vegetation covers 29,7600ha

Bush land: A bush is described as a multi - stemmed woody plant taller than 2m. Bush land commonly occupies sites too dry for wood land. It can also occupy sites which are insufficiently drained to support wood land, which are common in some low lands. Extensive potential large scale irrigation development schemes have been identified with in this group. The land cover type occupies about 4 million ha.

Shrub land: Shrub are differentiated from bushes on the basis of size, with areas dominated by plants < 2m tall. Shrub land covers an area of 4.5 million ha in Oromia.

Grassland: The most significant land cover type in Oromia is grass. It occurs throughout the region in one form or the other. Extensive southern Borena, Bale and low land east Harereghe rangelands are mapped under this category.

Grass land covers about 10.3 million ha which is nearly 32% of the region. Most of the grass lands and grass lands mixed with bush and shrub land and also grass land mixed with scattered wood land are under the National parks, wild life reserves, sanctuaries and controlled hunting areas. Integrated range land development including human and livestock water supply, irrigated pasture development will be an interest of water resource development. Water harvesting and Spate irrigation is appropriate in this land use type.

Swamp and marshes: These are areas seasonally water logged for a few months per year, where for the rest of the year they may be used for dry season grazing. Perennial swamp, by contrast is water logged for most of the year. Wet land drainage, rice production and dry season grazing are potential development related to water resource planning. More over they can be used as a storage reservoir in water resource development. Finchaa is a good example. These land cover types cover 53,000 ha in Oromia

Waste lands: This land cover type include rock out crops, salt flats, sand dunes and lava flows. They occupy

776,800 ha of Oromia. These area need to be reclaimed to bring in water resource development. How ever, this land use type attracts the interest of contract engineer as they are a rich source of construction materials for water resource development schemes.

Water Body: This consists of lakes and large reservoirs, small crater lakes and basin lakes found in the high land and mid lands. They cover an area of 862,200 ha.. Lakes are useful in multipurpose water resource development such as fishery/aquatic farming, irrigation, hydropower and water supply. For example Lake Ziway and Finchaa are used for irrigation and hydropower respectively.

5. Results and Discussion.

5.1 Land use conflict in water shed management

Land use on the upper stream conflicts with down stream. The conflicts reflected through erosion and sedimentation with a resultant effect of, change in run off system and base flow; increase or decrease in the frequency and severity of flooding, loss of water resources and finally an imbalance of the hydrological system in particular and an ecosystem in general.

Erosion and deposition of sediment leads to damage of vegetation, reduction in the permeability of soil where it is deposited, reduces the depth and area of the reservoir and finally leads to abandonment before its life period. Reservoirs such as Koka, Melka Wakana and Finchaa are under a serious threat. It also decreases the bed level there by over flowing and flooding the surrounding and down stream lands, which results in loss of both water and land resources.

More over catchement erosion increases run-off which reduce perching in to the soil to recharge the ground water aquifer system.

On top of this erosion and sedimentation changes or deteriorates the quality of both river and lake water. With increased use of commercial fertilizers and pesticides, the conflict will be aggravated.

Sediments have a high nutrient content and increase/maintains land productivity. Alluvial and colluvial sediments and their importance to support, cropping, grazing and vegetation cover in flood plains of the region indicates a. compliment of the land use system

The major cause of loss of soil and water in catchement is lack of permanent vegetation cover as a result of land use conflict. Vegetation is cleared for agricultural settlement and fuel wood purpose. The absence of fallow and shifting cultivation enhances the conflict. More over steepy hills and mountains are cultivated with out proper land management practices. It is usually advocated that steep areas more than 30 % slope should not be cultivated. In practice cultivation has climbed up to the top of the mountains as high as 3000 masl. These areas could have been left to "Area Closure" to sustain the natural vegetation or to revegetate grass, shrubs bushy and other permanent covers. Grazing also aggravates detachment and loss of soil and water. Cut and carry of grass and woods reduce the conflict.

Table 1. Summary of land use conflict in water shed management

Land use type	level of conflict	cause of conflict
Cultivation (including irrigation)	3	clearing of the water shed from permanent vegetation
Grazing	2	over grazing & trampling
Forest production	2	deforestation
Urban/settlement	3	encroaching in to the fragile part of the water shed
Wild life parks	4	protects watershed

Legend
0= Insignificant 1= Slight 2= Moderate 3= High
4= complementary/supplementary

Solomon Abata (1994), in his study of Metu area has found a land use conflict in water shed management. Run-off ranged from 3.6% under forest coffee, 31% under grass fallow to as 80% on cultivated land. A summary of major land use conflict in water shed management of Oromia is shown in Table 1.

Table 2. Land use conflicts in existing water resource development

Existing projects	Type of scheme	Rainfed cultivation	Grazing	Forestry	Wild life	Rural Settlement
Upper Awash						
Wonji estate	diversion	3	1	1	3	3
Nura era	diversion	3	1	3	3	1
Tibila	diversion	3	1	1	3	1
Metehara	diversion	1	1	1	1	3
Koka Dam	storage	1	3	0	0	3
Dire & Legedadi water supply	storage	1	3	2	1	3
Upper Rift valley						
Ziway state farm	diversion	3	1	1	3	3
Meki ziway Irrigation	diversion	1	3	3	1	3
Meki ziway out growers farms	diversion	1	3	3	3	1
Abbay basin						
Finchaa dam	storage	1	1	1	1	1
Finchaa estate	diversion	1	3	3	2	1
Baro basin	none					
Gibe basin	none					
Wabi Shebele basin						
Melka Wakena	storage	1	1	0	1	1
Genale Dawa	none					

Legend
0= Insignificant 1= Slight 2= Moderate 3= High
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5.2. Land use conflict in existing water resource development

Irrigation, hydropower and water supply development involves the construction of large reservoirs , storage dams , ponds and conveyance structures. This results in land use conflict with, cultivated land, grazing land , forest and wild life parks. Besides, construction of storage, canals, drains and crossing structures creates impediment to movement of people , live stock and wild animals. More over, construction of storage system may require realignment of the roads.

Development of water resource projects in the Oromia part of upper Awash basin have dislocated the cultivators and pastoralists. The lands most suitable for irrigated developments are those adjacent to the river course and susceptible to seasonal flooding. This permitted subsequent dry season grazing when grass on the extensive range lands had dried up or exhausted. Reduction of dry season flow affected riverine grazing lands which saves the lives of animals in time of drought . Such grazing areas may even be used by high landers in time of emergencies.

More over, several areas adjacent to and surrounding the irrigated areas are declared as wild life parks. It is ecologically appropriate, but left only a foot hill corridors for the local inhabitants.

Development of irrigation and other development in the rift valley lakes basin has resulted in similar conflict.

The construction of Finchaa dam and subsequent inundation of the Chomen swamp has resulted in the loss

Table 3. Land use conflicts in proposed water resource development

Land use type	Urbanization	Forest Industry	Rainfed agriculture	Livestock Production	Mining & industry	Tourism & recreation
Urban & built -up area	0	2	2	2	2	4
Forest & wood land	2	0	3	2	1	4
Cultivated area	2	2	0	3	1	1
Grazing land	2	2	3	0	1	1
wild life Parks	0	2	3	2	2	4
Rural settlement	0	1	2	2	2	1
Swamp & Water bodies	2	4	2	2	2	4

Legend
0= Insignificant 1= Slight 2= Moderate 3= High
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of the traditional grazing land. This forces concentration of animals on the shore of the new chomen lake and small scattered areas in the upper parts of the surrounding hill sides. The conflict in land use , in this area created overgrazing and erosion.

Construction of Melka wekana hydropower storage displaced cultivation , grazing and home stead of local inhabitants. Land use conflict of some existing water resource development projects were evaluated and the result is shown in Table 2.

5.3. Land use conflicts in Proposed water resource development

It is possible to make prediction of land use conflict in proposed development project based on historical information and base line survey of existing conditions. An assessment of planned water resource development reveals, loss of agricultural and grazing land , displacement of the inhabitants and the wild life.

Land use conflict of major proposed water resource development projects were evaluated and the result is shown in Table 3.

5.4. Land use conflict in other developments.

Several sectoral and subsectoral development planning and management have usually resulted in land use conflicts. Investigation of major developments in urbanization, forest production, rain fed agriculture, live stock production , mining and industry in oromia reveals that there is a land use conflict with forest, cultivated and grazing area, rural settlements and wild life parks.

Resettlement programs have been carried out as means of moving people from degraded lands to rehabilitate them on potentially high but under utilized and sparsely populated parts of the country. In line with this few of the previous resettlement programs in Oromia Region have been more or less successful. However, with increasing population and demand for more cultivated land and fuel wood the resettlers and local farmers have been started clearing the only remained belt of tropical rain forest in Illubabor, West and East Wellega zone.

Voluntary restellers from Hararghe and Arsi zone moved to southern Bale in Mena - Angetu Wereda. They are clearing the dense forest of wildlife habitat in Shewe-meselo area for cultivation, homestead , construction and fuel wood. Unless controlled they will shortly move in to the Bale Mountain National Park and devoid the area from any types of vegetation and animals. People from different part of the country are settled by self intiation in Anger Gutin area of East Wellega in search for agricultural land. They cleared the wood and bush land for cultivation. Though development of such remote area is encouraging, land use conflict is not yet got attention of the concerned agencies.

The lowland (an extensive part of the region) is sparsely populated, due to harsh environmental conditions and the prevalence of both human and live-stock disease such as Malaria, Tse - Tse fly and the likes. On the other hand in high and mid altitude areas, there are serious land use competitions and conflicts.

A common conflict in Oromia is between agriculture and urban development. Despite the fact that, urban development is much more adaptable to poor quality land (including waste land) than agriculture, the study have found urbanization develops at the expense of loosing agriculture land and forest areas. Addis Ababa and surrounding satellite towns such as Deberzeit, Sendefa, Holleta, Sebata, Ambo, welliso, etc. are a good examples. Expansion of all Zonal , wereda and other commercial towns depecits the same problem.

In the high land of Bale zone there is a land use competition between Melka Wakana reservoir and settlements/farmers. Farmers are settled in the periphery of the reservoir and cultivating the shore of the reservoir.

Of all the most serious is a land use conflict in Bale mountains National Park between settlement/farm land and grazing. The land holding of the park is 2,200km2. About 20% of the park has suffered from interference by local inhabitants in one way or the other. About 5% of the area is already cultivated. This figure is expected to increase every year, unless mitigation measures are taken. Grazing of livestock in the park is going to create a serious problem as it degrades the grasses and other vegetation there by creating an imballance of the food webs in the wild animals population. Such land use conflict lead to loss of biodiversity.

There is also a land use conflict between cultivation and range land. In Borana zone, the high landers influx to low land ranges and have started cultivating the best pasture land. SORDU study has reported, disturbance of the range ecology and reduced carrying capacity of the range land due to

Table . 4. Land use conflict in other developments

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Cultivated area	2	2	0	3	1	1
Grazing land	2	2	3	0	1	1
wild life Parks	0	2	3	2	2	4
Rural settlement	0	1	2	2	2	1
Swamp & Water bodies	2	4	2	2	2	4

Legend
0= Insignificant 1= Slight 2= Moderate 3= High
4= complementary/supplementary

encroachement of cultivation in the range land. Bushes and shrubs are also encroaching the grass lands there by aggaravating the situation.

In East Shewa, there are several commercial farms, industries and game reserves. On the other hand pastoralists and cultivators are squeezed to pockets of grazing and farm land.

In Jimma and Illubabor coffee plantation is expanding by clearing of forest with only some shade trees left.

On the other hand development of tourism and recreation have a complementary/supplementary land use effect rather than creating a land use conflict.

Extensive field investigation in all zones of the region and analysis has enabled us to summarize level of land use conflict as shown in Table 4

6. Conclusion and Recommendation

Any development results in change of land use. Change of land use brings land use conflicts In water resource development there are multiple land use conflicts. Land has several potential use depending on the interest and demand of the user. However there are always best alternative activities to put on land, to minimize land use conflict

Development of water resources enhances encroachment in to agricultural, grazing , forest land and national parks. Construction of reservoirs, conveyance infrastructures of water resource schemes displaces the local inhabitants.

The evaluation of the level of conflict would give a basic indication of the effect and help planners, decision makers and managers in formulation of sustainable water resource development. How ever there is a gap in identifying and evaluating the conflicts

There is lack of an awareness on the land use conflict and its effect by those of us involved in planning , development and research

More over ther is an absence of clear and simplified objective methedological tools to identify and quantify the effects.,

Investigation and analysis of land use conflict in water resource development has enabled to forward the following recommendations for concerned and relevant agencies.

Promote participation of beneficiaries, stake holders in all level of project planning and executing process.

Device land use conflict, investigation and evaluation Procedures and make detail analysis before commissioning of any water resource development projects

Prepare a policy and strategy of land use plan, which minimize land use conflict through formulation of alternative development options

Prepare fair compensation policy, which possibly allows other methods of compensation instead of direct payment

Provide the significant amount of the income from the project to enhance local development on continuos basis

Intigrate the benificiaries in the water resource development projects as outgrowers system

Re- plan and /or redesign some of the projects where the land use conflict is beyond the thresh hold level .

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Land Use Patterns and its Implication to Hare Watershed Managment South Rift Valley of Ethiopia

Engdawork Assefa AWTI

Abstract

The paper examines the distribution of land use and land cover at different points of time (1966/67 and 1974) and identifies the rate of changes in Hare watershed, south Rift Valley of Ethiopia. Moreover, it characterizes the watershed and examines the impacts of land use patterns on the watershed management. The study is based on interpretation and analysis of aerial photos of different periods. Semi-structured questionnaires, group discussion and silent survey were have also conducted. Forest land, woodland, bush land shrub land and grass land declined by 68%,87%,80%,171% respectively in 1974 compared to 1966/67. During the same period of time on the other hand cultivated land and others (barren land, and swamp land) increased by 18 & 59 percents respectively. The watershed is severely affected by soil degradation, silitation, flooding and water logging problem. As the land use patterns indicates, the deforestation rate is very high. And the yield of the area is declining even in good rain fall period. The major cause of these problem is the unwise use of land resources. Therefore measures should be taken in accordance with the problems that correct overgrazing, deforestation, inappropriate agricultural system and the low level of conservation measures.

1. Introduction

The significance of identifying land use /land cover patterns in the watershed enables us to establish the status of ecology of the agroecolgical zone and the impacts of man on the environment. It also enable us to suggest some points on situation of the sustainable use of the land and there by on watershed management planning.

Land use/ land cover is the result of the interaction of man and land. The exploitative activities of people and their different land use systems, accentuated by population are the main cause of land degradation. The high rate of deforestation, the poor management of land and other activities also result in reduction in soil productivity.

Soil erosion is the main cause of deterioration of the watershed in Ethiopia which is mainly the result of the mis-use of land. About 1,900 million tons of soil per year is being eroded from the highlands of Ethiopia (constable, 1984: XIV-XV).In general the topsoil erosion by far exceeds the formation. The soil formation rate is estimated at 5 to 10 tons/ha whereas the average soil loss from arable land is about 6 times as much as the rate of soil formation. This leads to the net reduction in soil depth by 4mm per year (NCS, 1990:15). Hence, out of the total are the highlands of Ethiopia, about 34.5% is marked by depth of less than 35cm, and 10% by depth of below 10 cm (NCS, 1990). These shallow soils are characterized by very low moisture holding and infiltration capacities, and hence undermine the ability of crops to withstand drought so as exacerbate the decline in crop yield.

The investigation of the extent, causes and consequences of watershed problems is vital to recognize the repercussion of the environment by the growing population, and the threats to the productive capacity of agriculture and there by the livelihood of population. Accordingly, it is important in providing information to work out production system and conservation measures. Equally important is the land use survey, which comprises the investigation, classification and mapping the pattern of land use and land cover, is also portray the status of resource utilization and land management. In such away as it provides basis to watershed management planners to plan for sustainable use of land.

The paper has the following objectives:

1.To describe and classify the nature and intensity of the present and past use of land by man and then to identify the trends and dynamics of land use and cover.

2.To characterize the watershed and there by to investigate the extent of deterioration of the watershed and the impacts of land use/ land cover on the watershed.

3.To suggest some points to conserve & improve the watershed for sustainable use.

2.Description Of The Watershed

Location:

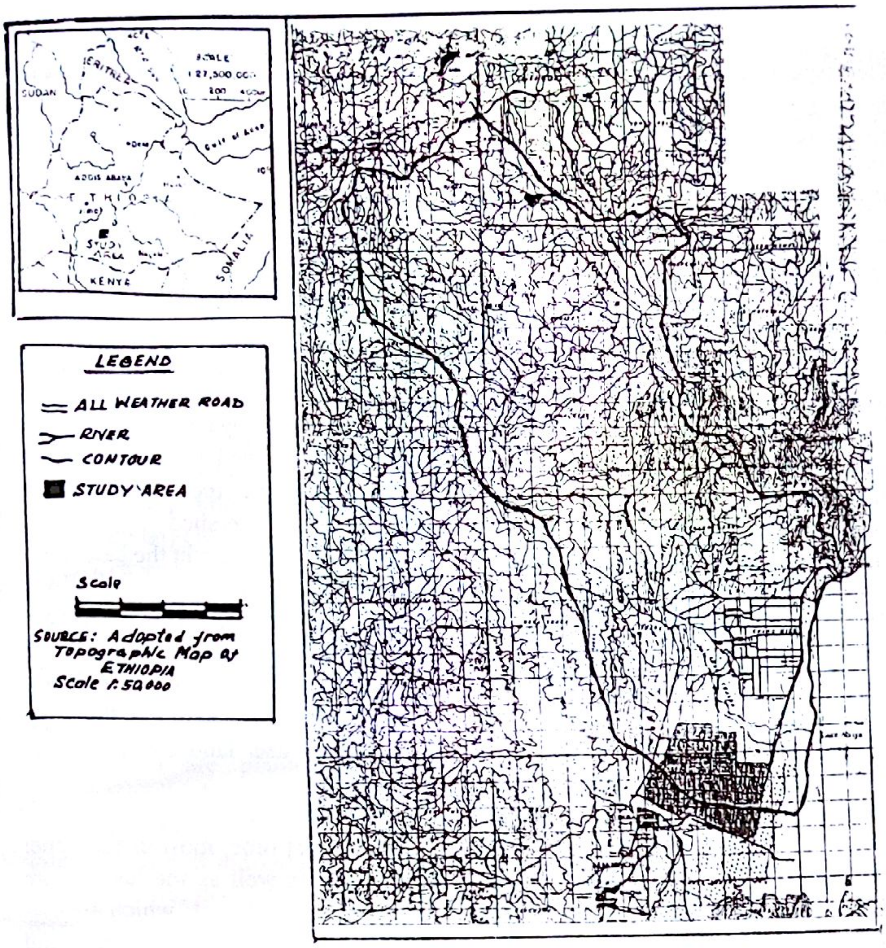
The study site "Hare watershed" is situated in Lake Abya Chamo basin south Rift Valley of Ethiopia. It is located about 493km south of Addis Ababa and about 7km NNW of Arbamich and is crossed by Addis Ababa -Arbaminch asphalt road. Astronomically the catchment lies 6°2'-6°18'N and 37°27'-37°38°E (Fig 1).

The watershed includes parts of Arbaminch Zuria wereda and Chencha wereda of North Omo Zone, South Nation Nationality and People State.

It has an altitude ranging from 1200 to 3480 and consequently the catchment exhibits kola (warm temperate) to Dega (very cool) climate.

Drainage Pattern

The Hare river catchment is bounded in the north by Surra 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.



Hare river originated in near Lanta area and flowing to south east direction, ending in lake Abaya. The catchment orientation is NW-SE and its extent is 52km. The catchment maximum width is about 10 km, covering an area of 25,000 ha.

Maximum river flow occurs between April 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 Hare River is no exception. The pattern of topography is composed of flat plain (around Lake Abya), hills (rift valley escarpment) and mountains (the upper catchment). Moreover, faults occurs along the eastern boundary of hills (King and Brachall, 1975).

The catchment is characterized by slopes ranging from flat to steep slopes. Of which, the sloppy topography comprises the largest proportion

The ancient basement rocks of the mountain escarpment overlain by Ignimbrite, basalt and tuff while the rocks of lower catchement are colluvium, alluvium and lacustrine which are derived from the above rocks (Geological map of Ethiopia, 1975).

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 751.9mm 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. 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.

On there hand, the rainfall distribution in highlands, is monomadal, which occurs from April to October. This due to when moist wind from the Atlantic and Indian Oceans converge over the highlands.

The mean average temperature in the lower catchment ranges from 22°c to 24°c. In the highlands the range is in between 13°c to 15°c. The variation is mainly due to altitude difference.

Based on the Hurni (1986) classification of climate of the Ethiopia ,the catchement area fall in to the following climatic zone.

A.Dry Kolla -lower catchment (1200-1500m)

B.Dry and wet Weyna Dega - Middle catchment (1500-2300m)

C.Moist Dega-upper catchment (2300-3200m).

Soils

The major soil units identified in the area are Eutric Nitisols, Eutric Regoslos and calcaric Fluvisols (UNDP/FAO 1984.). The distribution of soils in different parts of the catchment as follows:

A.Upper Watershed
Type- Eutric Nitisols
Texture- fine, deep clay loam to silty clay loam
Landform- rolling to hilly (moderate to very steep)
Color- redish brown, with free drainage ability

B.Middle Watershed Area.
Type - Eutric Regosols
Texture- stony loam & clay loam
Landform- medium strongly dissection to mountainous
Colour-brown color, often shallow
Parent material- ignimbrite or lava origin.

C. Lower Watershed Area
Type- calcaric Fluvisol
Texture- medium sandy loam, loam, sandy clay to loam very deep.
Slope -level to gentle slope
Colour-brown (light)
Parent material- riverine or lacustrine alluvium derived from basalt, ignimbrite, lava or ash.

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/km². The main ethnic groups are Gamo, Dorze and Ochollo. Their languge is Gamugna, which is spoken by 95% of the population. Other languages are Ocholigna and

Amharic.(Survey of Agricultural Office)

The major source of income is agriculture production of crops and raises of cattle. The people also involve in off-farm activities such as weaving, trading and handcrafts. In the catchmnt there are 12 elementary school but about 78% if the population is illiterate (Survey of Agricultural Survey).

3. Materials and Methods

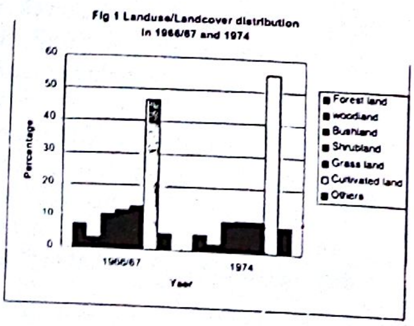
The data generated for land use and land cover analysis was the area distribution and percentages of different land cover types of 1967 and 1974. This information was acquired through stereoscopic aerial photo interpretation. Field survey was also carried out to collect data on the current land use/land cover. The land uses and land cover were grouped into forest, wood lands, bush land, shrub land grass land & cultivated land based on the physiognomic vegetation classification system of the FAO(1985).

Questionnaires were also, prepared and conducted in order to secure information about land use, history of cultivation, cropping patterns, soil management etc. In addition, silent observation, discussion and interview with elders, officials and farmers were carried out to supplement questionnaires.

4. Landuse/ Landcover Units and Spatial Distribution

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.

As depicted in graph 1, in 1966/67



the respective proportion of cultivated land , grassland, shrub land, bush land , forest land and woodland is 46.8%, 13.6%, 12.3%. 11%. 7.6% and 3.5% while the remaining 5.2% is for areas which are barren lands, gorges, swamp and homesteads.

In 1974 the cultivated land accounts near to half of the land use/land cover of the catchmnts. The proportion of other unit such as grassland, shrub land, bush land, woodland, and forest lands was 9.75, 9.8, 9.6, 2.4 and 5 percent respectively.

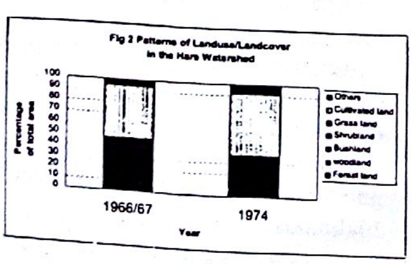
Likewise the dynamics in the past decade, the present cultivated land of the present time roughly estimated to 75% of the total land area which is followed by bushes and wcod land (12%), grassland 8% and forest (5%) (Survey Agriculture Office).

The lower catchment is gently slope and the types of landuse/landcover include natural forst land, grassland and cultivation which is dominantly used for perennial crops. In upper catchement, although some pockets of natural forests and planted forest, most of the land including the mountains are put under cultivation.

5. Patterns of Change in Land Use/Land over

The dynamics interaction between social & environmental changes resulted in the temporal- spatial change of landuse/landcover. Hence, the dynamics of land use/land cover is an inherent phenomena.

As depicted from the graph 2 the major change on landuse/landcover of 1974 compare to 1966/67 was forest cover which was declined by 67% . On the other hand the cultivated land in 1974 increased by 60% compare to 1966. Moreover, the bare land also increased while woodland , bush land, shrub land, and grassland declined by 68%, 87% 80%, 70.7% respectively in 1974 compare to 1966/67.



6. Impacts of Landuse Pattern on the Status of Hare Watershed

Watershed management implies the wise use of soil and water which is the function of the ways people exploit the land for different purpose. Thus, the problems related to watershed mainly derived from the ways people use the land. Therefore the land use/land cover pattern indicates the status of resources in the watershed.

The main land use in the catchment include growing crops, livestock production, collection of wood for fire and sale, shema weaving, bee keeping and fishing. The discussion under below clearly indicates the extent of the influence of land use/ land cover on Hare watershed.

1.Wood Resources

In the past time, most of the upper catchments as well as the lake shore were covered by forests which are evidenced by the highland climate and remnants of forests in church compounds and in some pockets of land.

The different uses of forests (woodlands) categorized in to:

A) Non-wood forest product-such as bee keeping, grazing/browsing, medicinal plants, incense/gum, fruits, bark rope, thatch grass.

B) wood products-including fuel wood, furniture construction wood, farm implements, and to construct boat and to make charcol.

Of these uses, the wood for fuel is the most significant. The near by towns, Arbaminch and Chencha, use wood for different purposes from the remaining woodland of the catchment , which suggests that wood products are becoming increasingly scarce.

At present, small proportion forest coverage, below 5%, is found in the lower catchment along the lake shore and Zede mountain ridge. In the upper catchment, pockts of natural forests are found in Dega Shara , Gugea, Meze and Mesho. The forests of the upper catchment which are found in areas of Surra ridge, mt Meze and Degena ridge are planted trees which was launched during Dreg regime (Fig 2).

In the year 1974-to 1979 the afforestation programme was launched in the catchement. The objective of the programme was to meet the growing demand for wood products mainly for fuel wood and to combat soil degradation, there by to maintain (protect) the existed natural forest.

During the period, Hare watershed was prioritized next to the west adjacent, Baso catchment , which was severely eroded and subsequently large area of it was afforested. For instance, in one peasant association up to 80 ha of land was planted by trees.

The programme has three different ownership targets. 1) government ownership 2) communality owner ship 3) individual ownership .

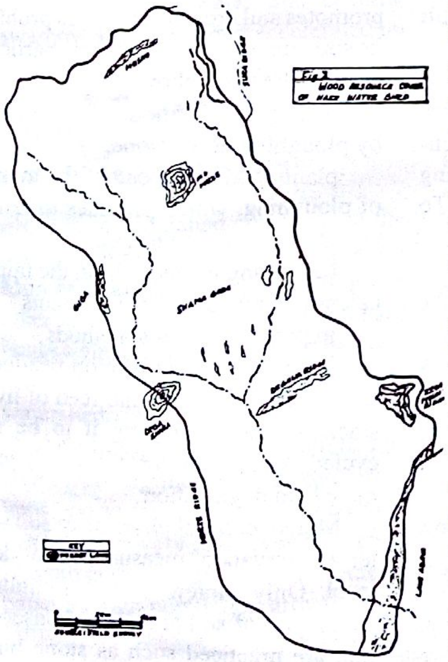
In the Hare upper watershed about 400 ha were afforested which was under the government owner ship. In the community ownership, about 16 ha and 20 ha of land are planted in lower catchemennt and upper catchement respectively. While there was no significant activities at individual level. The type of species planted in afforestation programme were Podocarpus, Juniperorss, Eucalyptus and Hagenia.

The dominant species of the natural forest include:

- In upper catchement: Erythina brceia, Hagenia abyssinica, Juniperous procerea,

Olea africana

-In lower catchement: Moringa olefera, Acacia tortilis, Eucalyptus camalandlenisis



-In lake shor: Croton macrostachyus, Acacia torilis, Acacia senegal

On the other hand some species are in threat of disappearance. These are Podocarpus, Acacia albida, Acacia nilotica, Arundo donax, Combretun molle, Cordia africana, Hygenia abysinia, Douyalis abyssinica and Juniperous procered.

2. Crop Production

The people of Hare watershed are mainly depend on agriculture in order to meet their basic needs and as a result the large proportion (>50%) of watershed is under cultivation. The peasants cultivate every available parcel of land which is suitable or marginally suitable for cropping. In the upper catchement more and more mountaion lands such as mountain slopes, summits and ridge top are brought under cultivation. The average land holding of the upper catchment is 0.5 to 0.7 ha where as 1.0-2.0 ha in the lower catchement.

The dominant types of crops grown in the lower catchment are maize and banana. While in the upper catchment the main crops are barely and wheat. The variation of crops are ascribed to climate variation.

Major crops, crop calendar and yields are given on tables 1-3. As the table 3 shows that, the yield is very low in the catchment.

In upper catchment, the people are entiriy dependent on rain fed. They grow only once in a year. The yield is very low even in good rainy period. On the other hand, irrigation is practiced in the lower cachment which encompasses 4 peasat association. The techniques of irrigation is traditional. The water is diverted from the main canal to each farm land. The watering is scheduled as, in one day 4 family heads water their land . The turn for each individual farmer is 21 days. The distribution of the water is controlled by the "water committee" established by 4 kebeles jointly. By using this water, farmers grow crops 2 times in a year (Belg/Meher) and as well as they grow perennial crops. However due to erratic rainfall & lack of reservoir the yield is declining.

To modernize the traditional techniques, the Lutheran mission constructedabout 7km long canal in 1997.The kollashara kebele is utilizing efficiently. The Chines company constructed weirs and 10 km long main canal but it was not completed.Moreover, weir as well as the canal have been filled by silts.

3. Livestock Production

Livestock raising, which is mainly dependent an grassland, is one of the integral activities of mixed farming. It provides farmers with draught power, as a means of transportation, and source of earning cash. The products of livestock such as meat, milk and its products are used for home consumption and the skins and hide also used as source of money earnings.

The livestock population distribution in the catchment is as follows:

Cattle	10,000-16,000
Oxen	6,000-9,000
Sheep	10,000-30,000
Goat	600-1500
Horses	2500-6000
Mules	300-900

(Source: Survey of Agricultural Office)

The total number of livestock in the watersheds is 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.

The most important sources of animal feed are common grazing land (50%). In the lower catchment along the lake shore which is also grazed by cattle from town . The utilization of this land is governed by pattern and intensity of rrainfall. During the main rain season on the catchment (May-Sept) since the area is flooded, the livestock are forced to stay out in the peripherial areas that is in the edges of the plain, and they also feed on lay, straw and the cut and

Table 1 Major types of crops in Hare watershade

crops	location	Distribution of the total area in respective catchment.
	Upper and Middle Catchment	
Baeley	-	30%
Potato	-	10%
Peas	-	10%
Beans	-	10%
Enset	Lower catchment	10%
Banana	-	30%
Swet potato	-	10%
Cotton	-	20%
Maize	-	30%
Others/manzo,vegta/	-	10%

Source: Survey of Agricultural Office

Table 2. Crop production in Hare watershed.

Crop	Yield Per Hectares In Quintal		
	Good Year Localy	Bad year Localy	Extensions Package
Barley	13	7	30
Wheat	12	8	36
Potato	80	40	200
Peas	4	2	12
Beans	4	2	10
Maize	15	10	50
Banana/1500/ trees per ha	150	60	-
Sweet potato	100	65	300
Cotton	12	6	30
Mango(75 tree per ha	70	40	210
Tomato	100	40	300
Pappeers	60	20	180

Source: Survey of Agricultural Office

carry grass from the bushes &woodlands of hills. This time is a period of recovery for the grass and some palatable species. Moreover at the beginning of the harvest of the lower catchment, the livestock move to the harvest field of the. Besides grazing over the common grazing land, people feed mainly oxen &milk cows the stored lay insets, stalks at home. In general, the production of livestock declines in quality and quantity.

7.Extent and Causes of Hare Watershed Problems

Hare watershed is one of the seriously deteriorated watershed as revealed by the unsustainable activate of the people. The major watershed problems are:

A. Soil degradation

The catchment is highly affected by the physical degradation which refers to the deterioration of the physical properties of soils. The dominant type is erosion by water which consists of sheet and rill erosion. Moreover, stream bank erosion is also common and as a result the direction of river is changed from time to time.

In consequence ,in the middle catchments, about 50% of the very top soil is washed away. In the ridge and hills about 75% of the original surface soil is removed irretrievably. Moreover, large areas of steep slope and summits are degraded badly. These area changed to barren land.

Furthermore, in the upper catchment, the deterioration of the humus content of soil is observed. There is also shortage of nitrogen and phosphorous in most cultivated land.

B. Flood damage

Flooding occurs in the lower catchement. The peak flood occurs 4 times with in 7 year. However, flooding occurs every year. By flooding except Chano Dorga pasant 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 drying. This rising of lake is mainly due to silitation and the change of climate.

The problem of flodding is a recent phenomena in the area. The main causes are:

1. high surface run- off in the upper catchment which is ascribede to deforestartion and misuse of land
2. the increse of the impermeability of the soil of the lower catchment by silitation.
3. lack of drainage on farm land and lack of flood control works.
4. poor irrigation water management.

C. Sedimentation problem

The lower part of the watershed is highly affected by silitation which is derived from eroded materials from the highlands. 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.

D.Water management problem

The irrigation water in the Hare catchment is used by traditional technique. This traditional way of watering plants has so many down sides.To mention few

a. farmers water their land until the allowed time to water ends irrespective of season. This is mainly due to the lack the calculated crop water requirement.

b.in the irrigated land, there is no drainage and as a result the water over lay on the field.

c. the uncontrolled high rate flow scour the soil.

d. there is no water reservoir and this prohibited the production of crops during dry season.

E. Water Logging

In the lower catchment, water logging is another major problems since the last 3years. By now it affected about 180 ha,, which is mainly found in Kolla Shara kebele. There are also pockets of areas of other kebeles..

The main cause of water logging is silts accumulated on farm land which lowers the permeability of the soil. The other cause is the irrigation system employed by farmers. It is using of irrigation water without the knowledge of crop- water requirement.

The main causes of the aforementioned problems are the unwise use of land of the watershed which embraces:

1. 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 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 country, accounts for 45% of the total soil loss while the soil in forest areas is negligible(1988).

2.Inappropriate Agricultural practices

In Hare watershed, the agricultural practices and agricultural land uses are characterized by:

·cultivation of the steep slope which promotes soil erosion as well as prohibits soil conservation measures, particularly on the slope above 22%

·preparation of fine seed bed for teff by ploughing down slope.

·planting after the end of the month of ploughing, which provides time for erosion to occur in the area.

·harvesting is practiced in the upper catchment by pulling out of plants

·improper fallowing methods

·inappropriate use of crop residues such as for fuel wood and feed of livestock instead of leaving it to be recycled. All these factors ultimately promote land degradation

Moreover the application of soil water conservation measures is at low level. Only in few places traditional techniques of soil and water conservation are practiced such as stone bund terrace, contour vegetation strip, tangay (nurse cropping) and cut off drainage. Although these practices have many advantages, they are not without limtation.

3. Over-Cultivation and Over-Grazing

The root cause of over-cultivation and over-grazing is the high population pressure. As the population increases (Daniel, 1989:23-28), land is fragmented frequencies of fallowing is reduced, and marginal lands are cultivated. The problem of land degradation is considerably aggravated when these situations are supported by outmoded practices of cultivation. This is true in Hare catchment where there is high population growth rate. The birth rate in North Omo zone is 3.5-5.0% and the density is 323 persons per square kilometer.

Excessive livestock population is amongst the principal causes of land degradation in the catchement. It leads to competition of grazing land with arable land. On the other hand, when more land is cultivated and crop residues are used for fuel wood and building materials, the feed resources of livestock decline. The reduction in grazing land and feed resources encourage overgrazing of the available land, and the situation worsens when supplemented by unrestricted grazing, concentration at drinking points and when attention is not given to production of animal feed. Furthermore, during the rainy season the livestock on the highlands graze on thelivestock on the highlands graze on the steep slopes since the valleys and plains are under water and become swampy. Thus erosion is accelerated on the slops.

8 Conclusions And Recomendations

In Hare watershed compared to the past, the forest cover & wood land resources declined enormously. On the other hand the cultivated land and bare land/swamp land increases. The later mainly indicates the deterioration of the watershed.

As a result of soil degradation, siltation, flooding and water logging problems, the agricultural production of the catchment is very low, even in a good rain fall period. This problem is exacerbated by high population growth rate, which require more food production.

The aforementioned problems of the watershed are mainly caused by unwise use of land including-deforestation, overgrazing inappropriate agricultural systems, over cultivation and low application of conservation measures. These factors are aggravated by population pressure.

Thus in order to rise the productivity of soil, understanding the types, extent and causes of the watershed problems is very crucial. The measures to overcome the problems should also be in accordance with types and magnitude of problems.

In lower catchement the main problems are silitation and flooding. The adjacent steep slope resulted in high surface runoff which floods the plain. To overcome the problem channeling of water to the possible direction required. Silitation and water logging in the area are caused by unwise use of the irrigation water. Therefore, the plant-water requirement to be fixed. Moreover, the present water logged area to be drained via cannel or by other means.

In the upper catchement, the main problem is lose of soils through erosion which affect the physical, biological and chemical properties of soils. To halt these problems, by investigating the indigenous soil-water conservation measures, by correcting the weak points and then to introduce to different places.

Deforestation is the main problem of the entire watershed. In order to improve or revert the situation it is clear that more trees should be planted in areas of devoid of vegetation cover and protect the existing vegetation to allow natural regeneration. Moreover, appropriate policies to protect the remaining natural resources should be devised of the regional and local level (in addition to the federal one) and followed by the establishment of law enforcing them.

Last but not least people should participate from perception to implementation phase of planning.. Furthermore, it is important to create awareness among people. There should also be substitution of fuel wood by other means such as biogas, stoves and the like. The concurred agricultural office should also get involved actively and building of their capacity required. The extension package programme shoild also consider soil water conservation as one component .

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Sub-Surface Drainage of Agricultural Lands

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Abstract

In the present study the worldwide historical overview of the drainage development has been sketched. Also, a critical review of the advances in the theory of sub-surface drainage has been presented. Currently available a few important and popular theories for the design of spacing of sub-surface drainage system have been used for demonstration farm of Arbaminch Water Technology Institute and a comparison has been made among these results. Based on this, it seems logical to use Dumm's (1968) equation or USBR (1978) graphical solution for the design of spacing of sub-surface drains for the unsteady state condition in the area under study. For steady state condition it seems reasonable to use Hooghoudt's (1940) equation or its Van Beers (1965) given by graphical solution for the design of spacing of subsurface drains. However, it will be worthwhile to take up pilot studies to the adopted drainage criteria and thereby arise at an optimum depth and spacing before embarking on large scale implementation of sub-surface drainage system for the area.

1.Introduction

Irrigated lands, even in arid regions, frequently require drainage. In fact, irrigation without drainage can be disastrous. Once-thriving civilizations based on irrigated agriculture in river valleys (as in Mesopotamia, for instance) have been destroyed through the insidious and for a time invisible process of salt accumulation caused by drainage congestion. Soil salinity has often become a long term problem associated with irrigated agriculture in the arid and semi-arid regions. But the problem can be controlled by good management of surface and ground water resources. Management of ground water is achieved through drainage, although drainage may not be necessary for sometime after the initial construction of a scheme. On the other hand, the presence of a shallow water table in the soil profile (provided it is not too shallow) can, in certain circumstances, be beneficial e. g., where precipitation or irrigation water is scarce, the availability of ground water of good quality within the reach of roots can supplement the water requirement of crops. However, to obtain any lasting benefit from the presence of a water table in the soil, its level and fluctuations must be controlled with the help of surface and/or sub-surface drains.

It is a truism which nevertheless bears repeating that water will not spontaneously flow out of the soil into a large cavity or drain unless the pressure of soil water is greater than the atmospheric pressure. Therefore, drains must be located below the water table to draw water and the water table cannot be lowered below the drains. Hence depth and spacing of drains are of crucial important. Inadequate depth of drain will prevent it from lowering the water table to the extent necessary. Too great a depth might, on the other hand, deprive the plants of a possibly important source of water during drought periods or whenever evapotranspiration exceeds precipitation.

The lower the hydraulic conductivity of the soil, the lower would be the drain spacing, which may sometimes make the provision of sub-surface drainage uneconomical. In humid areas, the drain depth may be shallow (for example, 1 m to 1.5 m) to provide good aeration conditions while the drain depth may have to be kept at 1.5 to 2.5 m where salinity is to be controlled, for example, in arid and semi-arid areas. In the present case, the spacing of drains for both steady and unsteady state conditions for Arbaminch Water Technology Inistitute demonstration farm has been determined with the help of a number of important drainage equations. Also the results are compared with each other. Apart from this, an overview of the development in the field of drainage and drainage equations have also been made.

2.World Wise Development of Drainage

In the present paper, it would not be possible to discuss the detailed history of drainage in all the countries. Nonetheless for a few countries, it is briefly highlighted as given below:

The history of drainage is as old as the human civilization. For the first time, the Greek historian Herodotus recorded the application of drainage in the Nile Valley as early as 400 BC by the inhabitants of ancient Egyptian civilization, (Chaunan, 1988). Throughout the middle east and the arid areas of Asia, agriculture is faced with the danger of increasing salinization of irrigated lands. This problem is not restricted to the developing world only. The salinity problem in the Imperial and the San Joachin Valley (both in the California state of the USA) questions both the relevance of reclamation techniques to the poorer countries of the world and the prices that may ultimately be paid by the environment of the area (Luthin, 1973).

The historical achievements of old world are Fens of England and Haarelem Lake of Holland. The ponline marshes of Italy as well as the projects of Lageronde and Forez in France are the notable works. Holland, a country with most acute land scarcity, embarked on removing water bodies by dyking and pumping forming 'polders' and these lands were used for urbanization and cultivation. Later Denmark undertook such reclamation works. In 1930, Admonsen marsh resulted in reclamation of 2, 35,000 ha of land. Belgium, Sweden, Poland, the then Czechoslovakia, Hungry and Bulgaria belong to this group. In Japan also gigantic wetland reclamation works were done (Roy, 1993).

In the USA. the tile drains were laid for the first time during the year 1835, on the farm of John Johnson of New York, who, later, came to be known as the father of tile drainage. The tile making machine was used in this country for the first time in 1848 (Luthin, 1973).

In India and Pakistan, it has long been accepted that some farm of drainage is ultimately required if irrigated agriculture is to continue on the Indus Plains. It is suggested that the delay in installing drainage is due to political expediency and financial castrants rather than a lack of appreciation of the problems caused by the delays. Further, drainage, unlike irrigation, is not popular with farmers. There mustlie a middle road between neglect and what may perhelps be seen as the ideal, a drainage system development over the same period as the irrigation project it serves.

In Pakistan seepage drains were constructed during 1933-1941. From 1944 onwards, comprehensive studies of drainage were undertaken through salinity control and reclamation projects (Roy, 1993).

In India, after opening of the lower Chenab canal in 1892, waterlogging and salinity were first noticed just a few years after its running. Similarly, salinity was observed in Moonak area of Karnal, Haryana. The Government of the Punjab carried out a survey in the lower Chenab Area in 1908 and constituted a waterlogging committee in 1925. In 1928 the waterlogging board was constituted and since independence, the Irrigation Research Institute at Amritsar has been doing this work. Inglis and Goklale (1928) carried out drainage studies at Baramati experimental farm and found sub-surface drains effective in lowering water table and thereby reducing salts. The Manjari scheme near Pune, India, in 1930 was also successful in lowering water table depth and reducing salinity with tile drains.

Year	Development
400 B C	Nile Valley
900 A D	North Sea
1408	Wind mills-Holland
1600	Open Channels
1810	Tiles – U.K.
1835	Tiles - U . S . A.
1865	Need Established in India
1875	Trenching machines
1960	Corrugated Plastic Tubes (CPT) in Europe and USA
1970	Laser Grade Control Technique
1980	Computer Modeling for example e.g. DRAINMOD

Table 1. History of World Drainage (Roy, 1993)

In Ethiopia, the Amibara Irrigation Project, as well as other potentially irrigable areas in the middle of the great Rift valley was identified in the survey of the Awash River basin. The feasibility study of the area concluded that the underlying aquifers possessed extremely low permeability and that as a result of irrigation, the water table could be expected to rise rapidly. Therefore, an adverse influence on crop yield was anticipated within 5 to 6 years after commissioning of the project. Further, it is estimated that in the middle valley areas alone, a total area in excess of 25,000 ha will ultimately require sub-surface drainage, if proposed irrigation projects are implemented (Tefera and Dfj, 1988). The complete historical development of drainage in the world is given in Table-1:

3. Development of Drainage Equations

Spacing between drains depends upon many factors but the texture and permeability of the soil, and the depth of drain below soil surface are significant items (Donnan, 1946). Several theories covering the flow of ground water to sub-surface drains and consequent drain spacing equations have been proposed during the past 50 years. The unsaturated flow condition though more exact, is comparatively more complex. Generally saturated flow principles are sufficient to provide drainage design procedures of reasonable accuracy. The saturated flow principles involve Darcy's law, Dupit-Forchheimer assumptions and the equation of continuity of flow. Combining these, one can obtain the one dimensional form of Boussinesq's (1904) equation which

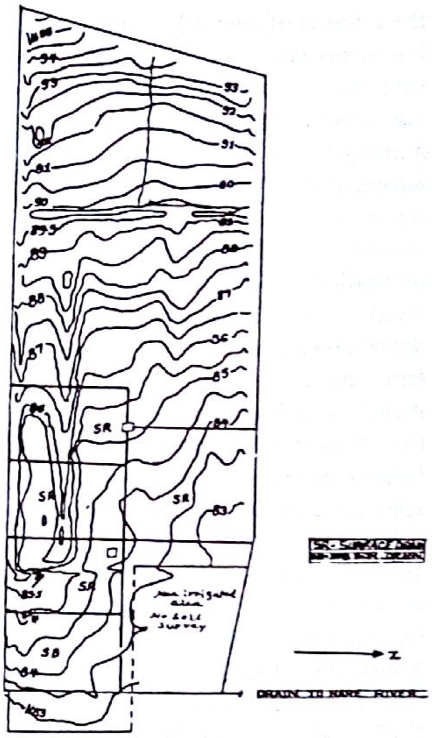

Fig. 1 Index Map of AWTI Farm (Scale 1:8000)

can be utilized to derive either steady state or unsteady state equations for design of spacing of drains for saturated flow condition. Steady state drainage equations are based on the assumption that the drain discharge equals the recharge to the ground water and consequently that the ground water table remains at the same position. Steady state equations are good for areas with humid climate and prolonged periods of fairly uniform medium intensity rainfall. Hooghoudt (1940), Kirkham (1958), Toksozo and Kirkham (1961), Childs (1968), Ernst (1962), Young (1985), van Beers (1965) and Smart and Herbertson (1992) are a few important investigators who gave solutions to the steady state drainage problem for homogeneous and isotropic soils. Some of these drainage equations are more accurate under certain conditions than others. In most cases the results obtained with these equations do not differ by more than 10%. The degree of uncertainty and the variations in determining the basic design parameters like hydraulic conductivity and depth of barrier layer is too much. Therefore, the equation which is most convenient to work with in the practical design should be chosen.

Boussinesq (1904) was perhaps one of the earliest authors who reported on the solution of unsteady state drainage. His theory was not much utilized at that time. It was Ferris (1950) who obtained the theory of sub-surface drainage for a homogeneous isotropic aquifer. Kirkham and Gaskel (1951) treated falling water table as a series of successive steady states and used the method for estimating drain spacing based on unsteady state conditions which relates the behaviour of the water table to time and drain spacing. Although this method was developed for use in a relatively flat area, laboratory research and field experience show that the method is applicable for areas having slopes up to 12% (Drainage Manual , 1978). There are many more developments in regards to unsteady state theories of drainage, for example, Amer and Luthin (1967), Yousif and Amer (1972) etc. However, for field applications Schilfgaarde's (1963) and Glover's solution as reported by Dumm (1954, 1968) or some of its modified form have been commonly used.

4. Spacing of Sub Surface Drains in the Study Area

Arbaminch Water Technology Institute demonstration farm (110.5 ha) is situated just adjacent to the Arbaminch state farm on its northern side at an altitude of 1190 m, latitude of 6.05° N and longitude of 37.38° E. The rainfall of Arbaminch is of bimodel pattern with mean annual rainfall of 790 mm. The average minimum and maximum temperature at Arbaminch are 13° C and 29.6° C respectively with the mean annual temperature being 21.3° C. The average relative humidity is 57% and the mean annual potential evapotranspiration is 1127 mm/year as per Thornthwaite's (1948) method. The climate of the area is classified as semi-arid. A substantial portion in the northern part of the demonstration farm is already out of cultivation due to the twin problem of water-logging and salinity. The index map of the farm is as given in Fig-1.

After investigation and soil tests, the two possible depths of sub-surface drain was estimated as 2.0 m and 2.3 m from the ground surface. The depth of water table midway above the drains is assumed to be 0.3 m and 0.5 m, respectively for the two depths of drains mentioned above for steady state condition. The depth of impervious layer below the drain was found to be at a depth greater than 13 m, therefore, it was assumed to be at an infinite depth from the ground surface.

The texture of the soil above drain level was found to be loam with the hydraulic conductivity equal to 0.6 m/day and the corresponding drainable pore space equal to 10 percent by volume. The drainage coefficient for steady state condition was found to be 5 mm/day based on soil type, irrigation interval, depth of irrigation and efficiency of irrigation. For unsteady state condition the adapted criteria was to drop the ground water table from the ground surface by 0.5 m in a period of 3 days. Based on these criteria, the spacing of drain for both steady and unsteady state conditions by using different drainage equations are as given in Table - 2 and 3 respectively.

SL NO	Names of Drainage Equation	Spacing of Subsurface Drains (m)	
		Depth of drain = 2.0 m	Depth of Drain = 2.3 m
		Height of water table mid way between the drain = 0.3 m	Height of water table mid - way between the drain = 0.5 m
1	Hooghoudt's (1940) Equation	27.0	41.5
2	Donnan's (1946) Equation	61.5	80.0
3	Toksoz and Kirkham's (1961) Graphical solution	25.0	39.0
4	Using nomograph of van Beers (1965)	27.5	40.0
5	Young's (1985) Equation	19.0	32.0
6	Smart and Herbertson's (1992) Equation	22.0	37.0

Table 2. Spacing of Subsurface Drains for the Project Area for Steady State Condition by Various Methods

SL NO	Names of Drainage Equation	Spacing of Subsurface Drains (m)	
		Depth of drain = 2.0 m	Depth of Drain = 2.3 m
		Height of water table mid way between the drain = 0.3 m	Height of water table mid - way between the drain = 0.5 m
1	Hooghoudt's (1940) Equation	27.0	41.5
2	Donnan's (1946) Equation	61.5	80.0
3	Toksoz and Kirkham's (1961) Graphical solution	25.0	39.0
4	Using nomograph of van Beers (1965)	27.5	40.0
5	Young's (1985) Equation	19.0	32.0
6	Smart and Herbertson's (1992) Equation	22.0	37.0

*The drawdown process as a sequence of small steps
**Total time for the water table to drop a succession of time increments

Table 3. Spacing of Subsurface Drains for the Project Area for Unsteady State Condition by Various Methods

Thus it can be observed from Table-2 that for steady state condition, Donnan's (1946) Equation gives the highest drain spacing among all the methods. It can be interpreted due to the fact that he did not consider the concept of Hooghoudt's equivalent depth. On the other hand, the other methods give very close results for steady state condition. The graphical solution of van Beers (1965) and the analytical solution of Hooghoudt (1940) give almost similar results. In fact, van Beers (1965) developed his graphs to simplify the tedious trial and error producere in Hooghowdt's (1940) method. Toksoz and Kirkham's (1961) graphical solution and Young's (1985) empirical formulae give almost the same drain spacing. For unsteady state condition van Schilfgaarde's (1963) equation gives highest value of drain spacing compared to the rest of the methods used in this study. It is interesting to note that rest of the methods for unsteady state condition give almost similar values of drain spacing as is evident from Table - 3. Thus for the design of drain spacing for sub-surface drains, it seems logical to use Hooghoudt's (1940) equation or van Beers's (1965) graphical solution for steady state condition. For unsteady state condition Dumm's (1968) equation or USBR (1978) graphical solution may be used fro design of spacing of sub-surface drains.

5. Summary and Conclusions

In the recent years the importance of good drainage in irrigated agriculture has come to be increasingly realized. Moreover areas which could not be utilized owing to an excess or lack of water are now being brought into cultivation by means of drainage and/or irrigation works. The application of the above simple equations developed for homogeneous soils requires the information about soil, aquifer properties, drainage flow system and existence or establishment of an appropriate drainage criteria. With the selection of an appropriate drainage criteria, the theories may be applied to obtain an approximate drain spacing. For the design of drain spacing for sub-surface drains, it seems logical to use Hooghoudt's (1940) equation or van Beers's (1965) graphical solution for steady state condition. For unsteady state condition Dumm's (1968) equation or USBR (1978) graphical solution may be used for design of spacing sub-surface drains. However, it may be worthwhile to take up pilot studies to test the adopted drainage criteria and to arrive at an optimum drain spacing before embarking on large scale implementation of sub-surface drainage in Ethiopia.

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Global Warming From An Enhanced Greenhouse Effect And Ozone Layer Depletion

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Abstract

Although our species has been on Earth for only an eyeblink of Earth's overall existence, we are now altering the chemical content of Earth's entire atmosphere to 100 times faster than its natural rate of change.

Largely invisible and silent, these ultimate problems will continue building until they trigger significant thresholds of change. When those thresholds are crossed, it will be too late to prevent the drastic, lasting, and unpredictable effects they have on the Earth that supports us and other species. There will be no place for us to escape to and no place to hide from the effects of these global changes. I will discuss the effect of deforestation on short term health of humans and on the long range health of the planet as a base for supporting life. It shows that dealing with these planetary emergencies to prevent the ultimate tragedy of the commons for our species and many other species will require significant changes in the way we think and act and international cooperation on an unprecedented scale.

1. Introduction

Earth's average surface temperatures and climate are the result of a number of interacting factors, which we only partially understand Throughout Earth's 4.6 billion years of existence, there have been pronounced changes in the composition of the atmosphere, geosphere, hydrosphere, and biosphere and in the nature of the interactions between these portions of the ecosphere . By examining the fossil evidence of climate-sensitive organisms and the composition of rock strata and ice cores, scientists have tried to piece together a crude picture of Earth's past climatic history.

This scientific detective work-which is preliminary and often speculative-suggests that the estimated average surface temperature of the earth has fluctuated considerable over geologic time. It indicates that over the past 800,000 years, there have been several great ice ages, during which much of the planet was covered with thick ice sheets. Each glacial period lasted about 100,000years and was followed by a warmer interglacial period lasting 10,000 to 12,500 years.

The last great ice age ended about 10,000 years ago. At the coldest point of that ice age, the mean temperature of Earth's surface was only about 5°C cooler than it is today. Thus, a fluctuation of this magnitude, up or down is considered a significant temperature change and leads to drastic changes in climate through out the world.

For the past 10,000 years, we have been enjoying the warmer temperatures (compared with those of the last ice age) of the latest interglacial period . During this period of favorable climate, Earth's mean surface temperature has risen about 5°C . Agriculture began and spread rapidly throughout the world to support the exponential increase in world population that this generally warmer climate allowed.

During the warm period we now live in, Earth's mean surface temperatures have fluctuated only moderately, typically up or down 0.5°C to 1°C over 100- to 200-year periods. These moderate and relatively slow fluctuations in climate has not led to drastic changes in the nature of soils and vegetation patterns throughout the world, thus allowing large in creases in food production.

The greatest threat to human food production and economic systems and to wildlife habitats is rapid climate change involving only a few degrees in Earth's mean surface temperature, taking place over a few decades. This would drastically alter the places where certain biomes and thus certain species could exist and would change conditions faster than some species, especially vegetation that supports animal species, could adapt and migrate to other areas. Such rapid changes in climate would shift the areas where we could grow food. Some areas would become uninhabitable because of lack of water or because of flooding from a rise in average sea levels.

2. Temperature, Climate And The Chemical Compositions Of The Atmosphere

The chemical composition of the troposphere and the stratosphere is and important factor determining the mean temperature of the planet's surface and thus its climate. Heat is trapped in the troposphere by a natural process called the greenhouse effect .

The amount of heat trapped depends mostly on the concentrations of various heat-trapping gases, known as greenhouse gases, in the troposphere. The principal greenhouse gases are carbon dioxide, water vapor (mostly in clouds), ozone, methane, nitrous oxide, and chlorofluorocarbons. Increase the concentrations of these gases faster than they are removed from the troposphere and Earth's mean surface temperature increases. Decrease their concentrations faster than they are emitted and Earth's mean surface temperature drops.

The two greenhouse gases with the largest concentrations in the troposphere are carbon dioxide and water vapor. Addition of carbon dioxide to the troposphere and removal from it are controlled mostly by the global gaseous carbon cycle , and the level of water vapor is controlled by the hydrologic cycle. Over the past 160,000 years, estimated levels of water vapor in the troposphere have remained fairly constant while those of carbon dioxide have fluctuated. Estimated changes in the carbon dioxide content of the troposphere during this period correlate fairly closely with variations in Earth's mean surface temperature.

3. Rising Levels Of Greenhouse Gases

Until recently, most green house gases were emitted and removed from the troposphere by Earth's major biogeo-chemical cycles without disruptive interferences from human activities. However, since the Industrial Revolution, and especially since 1950, we have been putting enormous quantities of greenhouse gases into the atmosphere primarily from the burning of fossil fuels (57%) . The use of chlorofluorcarbons (17%), agriculture (15%), and deforestation (80%). There is growing concern that these gases can amplify the natural greenhouse effect and turn up the planet's thermostat fairly rapidly.

Satellite and other measurements indicate that currently carbon dioxide accounts for about 49% of the annual human-caused input of green house gases, chlorofluorocarbons (CFCs) for 14%, methane for 18%, and nitrous oxide for 6 %. However, the last three gases have a much greater warming effect per molecule than carbon dioxide.

Carbon dioxide is released when carbon or any carbon-containing compound is burned. Fossil fuels provide almost 80% of the world's energy, cause about 75% of current Co_2 emissions, and produce most of the world's air pollution. Thus, the projected global warming crisis, along with greatly increased air pollution, is largely an energy crisis caused mostly by rapid, large scale, and wasteful burning of the world's fossil fuels.

To make matters worse, we are reducing Earth's ability to remove carbon dioxide through photosynthesis by deforestation around the globe. Deforestation, especially the wholesale clearing and burning of tropical forests, is believed to account for about 20% of the increase in carbon dioxide levels.

Modern farming, forestry, industries, and motor vehicles are also releasing other greenhouse gases mostly chlorofluorocarbons, methane, nitrous oxide, and ozone formed in smog-into the troposphere at an accelerating rate .

4. Projected Global Warming

The green house effect is one of the most widely accepted scientific theories. Scientists disagree, however, on how much average global temperature might rise as a result of our increasing inputs of green house gases into the atmosphere, whether other factors in the climate system will counteract or amplify a temperature rise, how fast temperatures might climb, and what the effects will be on various areas. The reasons for these disagreements are uncertainty about the accuracy of the mathematical models and geological evidence used to project changes in climate and assumptions about how rapidly we will consume fossil fuels and clear forests. Such controversy is a normal part of science .

Since1880, when reliable measurements began, mean global temperatures have risen about 0.5°C. However, there is no strong evidence linking this recent warming to an enhanced greenhouse effect. The reason we don't have a smoking gun is that, so far, any temperature changes caused by an enhanced greenhouse effect have been too small to exceed normal short-term swings in mean atmospheric temperatures.

The more pressing question, however, is what kind of climate is likely to develop over the next 50 to 60 years. Circumstantial evidence from the past and climatic modeling have convinced many climate experts that global warming will begin accelerating in the 2000s , rising above the background temperature changes (climatic noise) that presently mask such an effect.

Current climatic models project that Earth's mean surface temperature will rise 1.5°C to 5.5°C over the next 50 years (by 2050) if inputs of green gases continue to rise at the current rate . By way of comparison, the typical natural variation in Earth's mean surface temperature over periods of years 100 to 200 during the interglacial period we live in has been at most 0.5°C to 1°C .

Because of the many uncertainties in these global climate models their developers believe their projections are accurate within a factor of two. This means that projected global warming during the next century could be as low as 0.7°C or as high as 11°C. There is about a 50% chance either way. If we keep pumping greenhouse gases into the atmosphere and continue cutting down much of the world's forests, We are flipping a coin and gambling with life as we know it on this planet.

You might be wondering why we should worry about a rise of a few degrees in the mean temperature of Earth's surface. After all, we often have that much change between June and July or between yesterday and to day. The key point is that we are not talking about the normal swings in weather from place to place. We are talking about a projected global change in average climate in your lifetime, with much larger changes in various parts of the world. Global warming will alter not only temperature and precipitation, but winds, humidity, and cloud cover.

Current models indicate that the Northern Hemisphere will warm more and faster than the Southern Hemisphere, mostly because there is so much more ocean in the Southern Hemisphere and water takes longer to warm than land. Temperatures at middle and high latitudes are projected to rise two to three times the average increase, while temperature increases in tropical areas near the equator would be less than the global average. The United States, the Mediterranean, and much of China - the world's heavily populated mid-latitudes-could be hard-hit by such climate changes.

Projecting changes in mean global temperature is difficult enough, but it is easy compared with projecting climate changes in specific regions of the world. About all we can hope for is a series of scenarios of regional climate change based on feeding different assumptions into current and improved climatic models. Current climate models generally project the same results on a global basis but disagree widely on projected climate changes in different geographic regions.

One thing is clear, however. We now have the potential to bring about disruptive climate change at a rate 100 times faster than has occurred during the past 10,000 years. By the end of this century, the world could be warmer than at any time since the dinosaurs disappeared 65 million years ago, when alligators were found in what is now Antarctica was ice-free.

Such rapid global warming would be comparable to global nuclear war in its potential to cause sudden, unpredictable, and widespread disruption of ecological, economic, and social systems. The faster the change, the more unpredictable the results, and the harder it will be for society and the natural environment to cope with the consequences.

4.1 Possible Effects On Crop Production, Ecosystems, And Biodiversity

At first glance, a warmer average climate might seem desirable. It could lead to lower heating bills and longer growing seasons in middle and high latitudes. Crop yields might in crease in some areas because more carbon dioxide in the atmosphere can increase the rate of plant photosynthesis.

However, other factors could offset those effects. Use of air conditioning would increase and contribute more heat to the troposphere. That would intensify and spread urban heat islands ,causing people to use even more air conditioning. Using fossil fuels to produce more carbon dioxide and chlorofluorocarbons (used as coolants in air conditioners) to the atmosphere, accelerating global warming and ozone depletion. That would also add more nitrogen oxides and sulfur dioxide to the troposphere, increasing ground-level ozone, photochemical smog, and acid deposition.

Potential gains in crop yields from increased CO_2 levels could be wiped out by increased damage from insect pests, which breed more rapidly in warmer temperatures. Higher temperatures would also increase aerobic respiration rates of plants and reduce availability of water. Recent evidence suggests that many plants have responded to past Co_2 increases by developing fewer of the pores they use to take in Co_2 and thus reducing their rate of photosynthesis. Potential increases in crop yields could also be cancelled out by decreased yields as a result of ultraviolet radiation from depletion of ozone in the stratosphere.

Regional climate changes shift the ecological tolerance of species hundreds of kilometers horizontally and hundreds of meters vertically , with unpredictable consequences for natural systems and crops. Past evidence and computer models indicate that climate belts would shift north ward by about 161 kilometers (100miles) for each 1°C rise in the global atmospheric temperature. In other words, the wheatbelt climate that feeds much of the world would move northward.

Current and even improved climatic models won't be able to accurately project where such changes might occur, but the point is that there would be pronounced and unpredictable shifts in where we could grow food. The main reason we can grow so much food today is that global and regional climates have not changed much during the past 200 years.

Having to shift the location of much of our agricultural production in only a few decades would create great disruptions in food supplies and could lead to as many as 1 billion environmental refugees and mass starvation in some areas. Shifting crop production would also require huge investments in new dams, irrigation systems, water supply distribution systems, fertilizer plants, and other parts of our agricultural systems.

However, since the effects of rapid climate change would be largely unpredictable, we might do all that only to find that food-growing areas shift again if global warming accelerates or starts to drop. As millions of people are forced to migrate and then move again and as food and other resources are stretched to the limit, conflicts would erupt over what remains.

Current models indicate that food production could drop in many of the world's major agricultural regions, including the U.S. Midwestern grain belt ,the Canadian prairie provinces, the Ukraine, and northern China, because of reduced soil moisture in the summer growing season. Computer models suggest that by 2030, 10% to 30% of existing irrigated cropland in the western United States would be pulled out of production because of projected climatic changes. Parts of Africa and India and the northern reaches of Russia & Canada may get climates that could increase food production. However, soils in some of these potential new food-growing areas, such as Canada and Siberia, are poor and would take centuries to reach the productivity of current agricultural land. Meanwhile, food prices would skyrocket.

In some areas lakes, streams, and aquifers that have nourished ecosystems, cropfields, and cities for centuries could shrink or dry up altogether, forcing entire communities and populations to migrate to areas with adequate water supplies. The Gulf Stream might stop flowing northeastward as far as Europe, leading to a much colder climate in that part of the world.

Global warming might also speed up the bacterial decay of dead organic matter in the soil. That could lead to a rapid release of vast amounts of carbon dioxide from dry soils and methane from waterlogged wetlands and rice paddies. Huge amounts of methane tied up in hydrates in soils of the arctic tundra and in muds on the bottom of the Arctic Ocean could also be released if the blanket of permafrost covering tundra soils melts and the oceans warm. Because methane is such a potent greenhouse gas , this could greatly amplify global warming.

The spread of tropical climates from the equator would bring malaria, encephalitis, and other insect borne diseases to formerly temperate zones. Tropical skin diseases would also spread to many areas that now have a temperate climate.

In a warmer world, the frequency and intensity of highly damaging weather extremes, such as prolonged heat waves and droughts, would increase in many parts of the world. As the upper layers of seawater warm, the severity of hurricanes and typhoons would increase in some parts of the world. For example, computer models project that giant hurricanes, with 50% more destructive potential than those of today, would hit farther north and during more months of the year.

Changes in regional climate brought about by global warming would be a great threat to forests, especially those in temperate climates and the northern coniferous forests in regions with a subarctic climate. Least affected would probably be tropical rain forests, if we haven't cut most of them down.

As Earth warms, forest growth in temperate regions will move toward the poles and replace open tundra and some snow and ice. However, tree species in such forests can move only through the slow growth of new trees along their edges-typically about 0.9 kilometer a year or 9 kilometers per decade. If climate belts move faster than this very slow migration or if migration is blocked by cities, cropfields, highways, and other human barriers, then entire forests will wither and die. These diebacks could amplify the green house effect when the decaying trees release carbon dioxide into the air. Then the increased bacterial decay of organic matter in the warmer exposed soil would release even more CO_2.

Large-scale forest diebacks would also cause mass extinction of plant and animal species that couldn't migrate to new areas. Fish would die as temperatures soared in streams and lakes and as lower water levels concentrated pesticides.

There would be increased stress to trees from pests and disease microorganisms, which are able to adapt to climate change faster than trees are. The number of devastating fires in drier forest areas and grasslands would increase, adding more carbon dioxide to the atmosphere. Costly efforts to plant trees may fail when many of the new trees die.

· Any shifts in regional climate caused by an enhanced greenhouse effect would pose severe threats to many of the world's parks, wildlife reserves, wilderness areas, and wetlands and would accelerate the already-serious and increasing loss of Earth's biodiversity.

4.2 Possible Effects On Sea Levels

Water expands slightly when it is heated. This explains why global sea levels would rise if the oceans warm like heating the fluid in a thermometer. Additional rises would occur if the higher-than-average heating at the poles causes some, or even complete, melting of ice sheets and glaciers.

The Greenland and Antarctic ice sheets act like enormous mirrors to cool the earth by reflecting sun light back into space. Some scientists fear that even a small temperature rise would shrink these glaciers, allowing more sunlight to hit the earth. Global warming would amplify and cause a larger rise in average sea levels than that from the thermal expansion of water. If most of the Greenland and West Antarctic ice sheets melted, as happened during a warm period 150,00 years ago, sea levels would gradually rise as much as 6 meters over several hundred years.

Current models indicate that an increase in the average atmospheric temperature of 3°C (5°F) would raise the average global sea level by 0.2 to 1.5 meters over the next 50 to 100 years.

Approximately half of the world's population lives in coastal regions that wold be threatened or flooded by rising seas.

Even a modest rise in average sea level would flood coastal wetlands and low-lying cities and croplands, flood and move barrier islands further inland, and contaminate coastal aquifers with salt.

A one third-meter rise would push shorelines back about 30 meters (98 feet) compared with 136 meters (445 feet) for a 1.5-meter (5-foot) rise in the average sea level. Only a few of the most intensively developed resort areas along the U.S. coast have beaches wider than 30 meters at high tide.

Especially hard-hit would be North and South Carolina, where the slope of the shoreline is so gradual that a 0.3-meter (1-foof) rise in sea level would push the coastline back several kilometers.

A modest 1-meter rise would flood low lying areas of major cities such as Shanghai, Cairo, Bangkok, and Venice and large areas of agricultural lowlands and deltas in Egypt, Bangladesh, India, and China, where much of the world's rice is grown. With a 1.5-meter rise, many small low-lying islands like the Marshall Islands in the pacific, the Maldives (a series of about 1,200 islands off the west coast of India that are home to 200,000 people), and some Caribbean nations would cease to exist, creating a multitude of environmental refugees. Large areas of the wetlands that nourish the world's fisheries would also be destroyed.

5.Depletion Of Ozone In The Stratosphere

The vital ozone layer About 2 billion years ago, microorganisms living under water evolved with the ability to carry out photosynthesis. Gradually over millions of years, those organisms began adding oxygen to the atmosphere. As some of that oxygen drifted upward it reacted with incoming ultraviolet radiation and was converted to ozone in the stratosphere. Before this oxygen revolution began, life on Earth could exist only under water, where it was protected from the sun's intense ultraviolet rays.

Today, we and many types of plants and other animals survive because this thin gauze of ozone in the stratosphere keeps much of the harmful ultraviolet radiation (specifically given off by the sun from reaching Earth's surface.

Uses of chlorofluorocarbons and halons In 1974, chemists Sherwood Roland and Mario Molina theorized that human-made chlorofluorocarbons (CFCs), also known by their Du point trademark, Freons, were lowering the average concentration of ozone in the stratosphere and creating a global time bomb. They trap heat 25,00 times more efficiently than CO_2 No one suspected such a possibility when CFSs were developed in 1930.

The two most widely used CFCs are CFC-11 (trichlorofluoromethane) and CFC-12 (dichlorofluoromethane). When they were developed, these stable, odorless, nonflammable, nontoxic, and non-corrosive chemicals were a chemist's dream. Soon they were widely used as coolants in air conditioners and refrigerators and as propellants in aerosol spray cans. Now they are also used to clean electronic parts such as computer chips, as hospital sterilants, as fumigants for granaries and cargo holds, and to create the bubbles in polystyrene plastic foam (often called by its Du Pont trade name, Styrofoam), used for insulation and packaging.

Bromine-containing compounds, called halons, are also widely used, mostly in fire extinguishers. Other widely used ozone-destroying chemicals are carbon tetrachloride (used mostly as a solvent) and methyl chloroform, or 1,1,1,-trichloroethane (used as a cleaning solvent for metals and in more than 160 consumer products, such as correction fluid, dry-cleaning sprays, spray adhesives, and other aerosols).

Depletion of the ozone layer ozone is destroyed and replenished in the stratosphere by natural atmospheric chemical reactions and is maintained at a fairly stable level. However, there is much evidence that we are upsetting this balance and reducing the level of life-saving ozone in the stratosphere.

Spray cans, discarded or leaking refrigeration and air conditioning equipment, and the production and burning of plastic foam products release CFCs into the atmosphere. Depending on the type, CFCs are so unreactive that they stay intact in the atmosphere for 60 to 400 years. This gives them plenty of time to rise slowly through the troposphere until they reach the stratosphere. There, under the influence of high-energy UV radiation from the sun, they break down and release chlorine atoms, which speed up the breakdown of ozone (O_3) into O_2 and O.

Several other stable, chlorine-containing compounds, including widely used solvents such as methyl chloroform (1,1,1-trichloroethane) and carbon tetrachloride, also rise into the stratosphere and destroy ozone molecules. When fire extinguishers are used, their unreactive bromine-containing halon compounds enter the air and eventually reach the stratosphere, where they are broken apart by UV radiation. Each of their bromine atoms destroys hundreds of times more ozone molecules than a chlorine atom. All these compounds, especially CFCs, are also greenhouse gases that contribute to global warming during their trip through the troposphere .

5.1 Effects Of Ozone Depletion

With less ozone in the stratosphere, more biologically harmful ultraviolet-B radiation will reach Earth's surface. This form of UV radiation damages DNA molecules and can cause genetic defects on the outer surfaces of plants and animals, including your skin. Each 1 % loss of ozone leads to a 2% increase in the ultraviolet radiation striking Earth's surface and a 5% to 7% increase in skin cancer, including a 1% increase in deadly malignant melanoma . Other effects are:

· Suppression of the human immune system, which would reduce our defenses against a variety of infectious diseases, and effect similar to that of the AIDS virus.

· An increase in eye-burning photochemical smog and acid deposition in the troposphere.

· Decreased yields of important food crops such as corn, rice, soybeans, and wheat,

· Reduction in the growth of ocean phytoplankton that form the base of ocean food chains and webs and that help remove carbon dioxide from the atmosphere, Especially vulnerable are UV-sensitive.

6. Conclusion

We have two options for dealing with the global warming many scientists believe we have set in motion: slow it or adjust to its effects. Many experts believe that we must do both, with no time to lose.

The cures for this planetary crisis we have caused are controversial, difficult, and painful. If the models are correct, we are in the position of a long-time alcoholic whose doctor tells him that if he doesn't stop drinking now he will die. It will required a new global ethic based on economic growth which does not threaten nature.

We and many other species can learn to live under different climatic conditions, if we are given time to make the necessary changes. That explains why slowing down any significant climate change caused by our activities must become the top priority of our species worldwide .Otherwise, environmental and economic security could be threatened everywhere within a single generation.

The general guidelines for slowing global warming and Ozone depletion are to reduce our use of the five deadly C's: cars, coal, cattle, chlorofluorocarbons, and chain saws- and increase our use of the two Earth-saving C's: contraceptives and conservation.

To slow down the above problems the following measures should be taken

Prevention (Input) Approaches:- **Banning all production and uses of chlorofluorocarbons and halons. This is the easiest thing we can do because we can either do without these chemicals or phase in substitutes for their essential uses. It is also the best early test of world wide commitment to protecting the atmosphere from both global warming and ozone depletion.**

· Cutting current fossil-fuel use.

· Greatly improving energy efficiency. This is the quickest, cheapest, and most effective method to reduce emissions of CO_2 and other air pollutants during the next two to three decades

· Shifting to perpetual and renewable energy resources that do not emit CO_2.

· Increasing the use of nuclear power to produce electricity if a new generation of much safer reactors can be developed and the problem of how to store nuclear waste safely for thousands of years can be solved . However, improving energy efficiency is much quicker and safer and reduces emissions of CO_2 2.5 to 10 times more than nuclear power per dollar invested .

· Sharply reducing the use of coal, which emits 60% more carbon dioxide per unit of energy produced than any other fossil fuel. Using the world's estimated coal supplies would produce at least a six fold or eight fold increase in atmospheric carbon dioxide.

· Switching from coal to natural gas for producing electricity and high-temperature heat in countries, such as the United States and the Soviet Union, that have ample supplies of natural gas, which emits only half as much CO_2, per unit of energy as coal. Switching to natural gas also sharply reduces emissions of other air pollutants. Because burning natural gas still emits CO_2, this is only a short term method that helps buy time to switch to an age of energy efficiency and renewable energy. Also, a recent study indicates that methane leaking from natural gas distribution system has such a powerful green house effect that it could off set the benefits of switching from coal to natural gas.

· Capturing methane gas emitted by landfills and using it as a fuel. Burning this methane gas produces carbon dioxide, but each molecule of methane reaching the atmosphere causes about 25 times more global warming than each molecule of CO_2.

· Sharply reducing beef production to reduce the fossil-fuel inputs into agriculture, carbon dioxide released because of deforestation for grazing land ,and methane produced by the animals themselves. Producing the beef in only 20 hamburgers is responsible for the release of more carbon dioxide than 0.4 hectare (1 acre) of trees can absorb in a year.

· Halting unsustainable deforestation every where.

· Switching from unsustainable to sustainable agriculture . Worldwide, agriculture is responsible for about 15% of the green house gases we emit into the atmosphere. If developing countrys increase their use of unsustainable, industrialized agriculture, that percentage could rise.

· Slowing population growth. If we cut green house-gas emissions in half and population more than doubles, we are back where we started.

· Dismantling the global poverty trap to reduce unnecessary deaths, human suffering, and environmental degradation and to help developing countries help them selves and not follow the present throwaway industrial path of today's developed countries.

Cleanup (output) approaches:-

· Developing better methods to remove carbon dioxide from the smokestack emissions of coal burning power and industrial plants and from vehicle exhausts. If used, currently available methods would remove only about 30% of the CO_2 and would at least double the cost of electricity. Eventually, this approach would be overwhelmed by increased use of fossil fuels. Also, the recovered CO_2 must be kept out of the atmosphere, presumable by putting it in the deep ocean, spent oil and gas wells, and excavated salt caverns, or by reacting it with other substances to convert it to a solid such as limestone. The effectiveness and cost of these methods are unknown.

· Planting trees. Each of us should plant and care for at least one tree every six months. This is an important form of Earth care, especially in restoring deforested and degraded cropland and rangeland. However, we should recognize that tree planting is only a stopgap measure for slowing CO_2 emissions. To absorb the carbon dioxide we are now putting into the atmosphere each year, we would have to plant an average of 1,000 trees per person every year.

· Recycling CO_2 released in industrial processes.

· Removing CO_2 by photosynthesis by using tanks and ponds of marine algae or by fertilizing the oceans with iron to stimulate the growth of marine algae.

Adjusting to global warming:- Even if all the things just listed are done, we are still likely to experience some global warming, although at a more manageable rate. If we stopped adding greenhouse gases to the atmosphere now, current models indicate that what we have already added could warm the earth by 0.5°C to 1.8°C. Since there is a good chance that many of the things we should do will either not be done or be done too slowly, some analysts suggest that we should also begin preparing for the effects of long-term global warming. Their suggestions include

· increasing research on the breeding of food plants that need less water and plants that can thrive in water too salty for ordinary crops

· building dikes to protect coastal areas from flooding, as the Dutch have done for hundreds of years

· moving storage tanks of hazardous materials away from coastal areas

· banning new construction on low-lying coastal areas

· storing large supplies of key foods throughout the world as insurance against disruptions in food production

· expanding existing wilderness areas, parks, and wildlife refuges northward in the Northern Hemisphere and southward in the Southern Hemisphere and creating new wildlife reserves in these areas

· developing management plans for existing parks and reserves that take into account possible climate changes

· connecting existing and new wildlife reserves by corridors that would allow mobile species to change their geographic distributions and transplanting endangered species to new areas

· wasting less water

We have known about the possibility of an enhanced green house effect and its possible consequences for decades. We also know what needs to be done at the international, national local, and individual levels Research must be expanded to help clear up the uncertainties that continue to exist, but to most environmentalists and many climatologists that is no excuse for doing nothing or very little now.

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RS And PS Synergy For The Detection Of Chemical And Protein Decomposion Effluents To Lake Koka

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Abstract

The paper discusses on the potential application of Remote and proximal Sensing synergy for the detection of chemical and protein decomposition product effluents to Lake Koka. All the agro-industrial activities at the Lower Awash depend on the water quality of Koka. Therefore, the findings and the meliorative measures suggested in the paper are handy recommendation to the prefectural Government authorities to reinstate the ailing ecosystem of Koka.

1. Introduction

The Koka reservoir, sometimes also called as 'Bahre Gelila' was formed as a result of the concrete dam, which was completed in 1958. It was built by the Government of Italy as a war indemnity. After a year of retention time, it has flooded an area almost reaching 200 km² of acacia dominated savannah. The lake being exorheic is alimented chiefly by Awash River. Moreover, Mojo also empties to the lake.

The Koka reservoir was built to substitute the currently defunct Aba-Samuel hydroelectric station to meet the growing demand for city illumination and source of power. Apart from this, the reservoir was destined to supply irrigation water to then H.V.A (Hangel Vergin Amsterdam); a Dutch owned estate and electrical power to the Wonji Sugar Factory.

1.1Location

Koka reservoir is found within the mid- sector of the Ethiopian graben at an altitude of 1596m. It is nearly 100km southeast from Addis Abeba. The geographical location is f = 8°17'42" N-8°29'30"N and ? = 38°09'36"E.

1.2 Climate

So long as the Ethiopian rift experiences a double to foehn, the climate of the area is semi-arid (Gemechu, 1978). The aridity Index (P/ET) ranges from 0.5 to 1.0. The average temperature is between 14 C° to 20 C° during summer, the temperature reaches 30 C°.

1.3 Soil And Edaphic Conditions

Around the lake basin, both zonal and axonal types of soil are found. Since it within the 'Wonji fault belt', it is a volcanic area. All Well water at the small town of Koka are hot. The volcanic condition has an impact on the soil type of the area. Andosol group, especially vitric and molic with a bulk density of 0.85 g/cm². is the main soil type (National Atlas of Ethiopia, 1978). The western edge of Koka has a sodic phase which inhibits soil viability.

1.4 The Lake's Morphometric Indices

The lake's surface area (A). It is only in the case of man regulated lakes (reservoirs) that the surface area may be consider ' constant'. Lake Koka's surface area at 110.30 m is 236 km². At 102.0 m = 108 km².

Volume (V) . The volume of Koka (total storage capacity at 110.30 m) and the usable according to collateral sources shows a discrepancy. Total storage capacity at 110 m is 1850.10 ^{6} m³ (Ethiopian Electric Light and Power Authority, Feasibility studey, IVO, International LTD, June, 1987).

The axial length (L). The axial length Koka as measured from 1:50 000, topographic map using digital planimeter is 24 km.

The width of the lake (W). The width of the lake, which is the widest orthogonal distance to the axial length is 12.25 km.

The maximum depth (z). Disregarding siltations, just after its retention time, koka had had a maximum depth (Z_{max}) of 14.8 m. Its mean depth is nearly 8m. However, owing to siltation, the water column is fast lowering.

Shoreline Development (DL). Lake Koka is highly indented. The shoreline development (DL) is 2.08; therefore, it is and irregular lake.

2. Technical Approaches

Persuaded

2.1 Remote Sensing

2.1.1 Materials and equipment

Landsat TM multi-spectral data
Data package .... CD-ROM
Signature quantization level.....8 bit (o-255)
Ground IFOV..................30 m x 30 m
Swath width.......................185 km
Scale...............................large
Data acquisition..............1991 01 19

The two main approaches used in computer assisted image analysis and inter- pretation are *batch mode and interactive mode.* For this digital analysis, the interactive mode was applied.

Pollution anomaly detection with image enhancement. Image enhancement, which constitutes spectral and spatial were performed to make pollution anomalous sectors of the lake more discernible. Linear contrast stretching expands the narrow range of raw data to the total range to utilize the fullest capcity by clipping it 0 to 255. " Mathematically linear contrast stretching can be shown as" (Karl Heinz Szkielda, 1988).

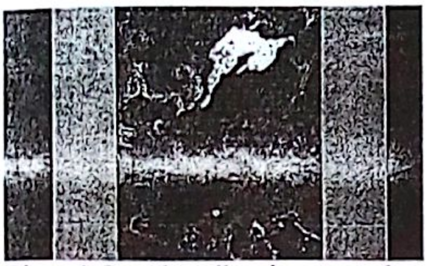

Plate .1 Grossly polluted sectors of Lake Koka

Bou = Bin - Min / Max - Min. 255
Bou = enhanced brightness value of pixel in output ranges.
Bin = brightness value of pixel in input.
Min = minimum brightness values.
Maix = maximum brightness.

Linear contrast stretching which is frequently being used in hydrological application by taking the digital values between 0 and 20 was not applied in this limnetic study of Koka. Since the lake is turbid, the stretching was done between 20 to 255. It is true that contrast stretching increases the contrast over a range, but the same contrast (slope) was not assigned. So, in order to attain a non- linear contrast on the raw Koka image, equalization of histogram was used.

It is true that unlike transparent lakes, pixels in cloudy lakes are non-homogeneous. Therefore, spatial frequency convolution high pass and Laplacian 5 x 5 matrix filter kernels were used. The combined effects of these successive enhancement techniques had enabled to discriminate the anomalous grossly polluted sectors of the lake (Plate 1).

Accordingly, the northwestern sector of the lake shows anomaly. To supplement the digital discrimination polluted sector, a 'Lake Truthing' was carried out. With a Secchi-disk and Hack YsI oxygen meter, the degree of pollution was estimated. At this anomalous sector, Secchi-disk disappearance on the average was 20-cm vis a-vis 100 cim in a transparent lake. This sector

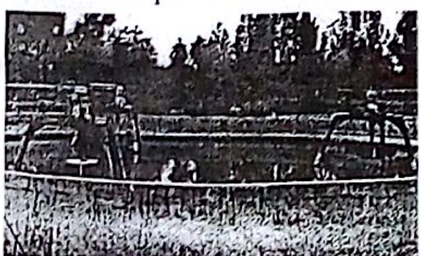

Plate 2 The Mojo Tannery's treatment Plant

Class	(Weight)/(Total Weight)	
1 Area of pollution mixing	0.67	
2 Reffle	0.67	
3 Temporarily inundated area	0.67	
4 Grass and scattered trees		0.67
5 Hydalophytes		0.67
6 Forest		0.67
7 Phytoplankton	0.67	
8 Grossly polluted water	0.67	
9 Lacustrine coastal mud flat	0.67	
10 Maize crop		0.67
11 Turbid water		0.67
12 Farmland		0.67
13 Litoral sector of the lake	0.67	
14 Settlement		0.67
15 Riparian vegetation		0.67

Band	Ave	Min
237	1998	1890

Class pairs

1:2	1:3	1:4	1:5	1:6	1:7	1:8
1:9	1:10	1:11	1:13	1:14	1:15	1:16
2:3	2:4	2:5	2:6	2:7	2:8	2:9
2:10	2:11	2:12	2:13	2:14	2:15	3:4
3:5	3:6	3:7	3:8	3:9	3:10	3:11
3:12	3:13	3:14	3:15	4:5	4:6	4:7
4:8	4:9	4:10	4:11	4:12	4:13	4:14
4:15	5:6	5:7	5:8	5:9	5:10	5:11
5:12	5:13	5:14	5:15	6:7	6:8	6:9
6:10	6:11	6:12	6:13	6:14	6:15	7:8
7:9	7:10	7:11	7:12	7:13	7:14	7:15
8:9	8:10	8:11	8:12	8:13	8:14	8:15
9:10	9:11	9:12	9:13	9:14	9:15	10:11
10:12	10:13	10:14	10:15	11:12	11:13	11:14
11:15	12:13	12:14	12:15	13:14	13:15	14:15

237	1198	1890

2000	2000	2000	2000	2000	2000	1996
2000	2000	1999	2000	2000	2000	2000
2000	2000	2000	2000	2000	2000	2000
2000	2000	2000	2000	2000	2000	2000
2000	2000	2000	2000	2000	2000	2000
1996	2000	2000	1943	2000	2000	2000
2000	2000	1999	2000	2000	2000	1980
2000	2000	2000	2000	2000	2000	2000
2000	2000	2000	2000	2000	2000	2000
2000	2000	1999	2000	2000	2000	2000
2000	2000	1890	2000	1999	2000	2000
2000	2000	2000	2000	2000	2000	2000
2000	2000	2000	2000	2000	2000	2000
2000	2000	2000	2000	2000	2000	2000
2000	2000	1961	1981	2000	2000	2000

Table 2 Signature separability listing Disance measure: Transformed Divergence Using 6 TM bands except the thermal band. Taken 3 at ati.ne

was an oxygen sag, where the Dissolved Oxygen (DO) was lest; merely 9% saturation up to 4 meter depth. It was observed that ot remove epidermal keratin, the factory uses $CaCO_3$ By and large, the Mojo tannery for fleshing, uphairing, liming, washing and deliming, bathing, pickling, chrome tanning and dyeing employs 250 chemicals including H_2SO_4. Out of the three lagoons, one is intended for H_2SO_4 and byproduct of bichromate. The two remaining are for protein decomposition Products and sulfide. The lagoons serve as waste reservoirs and vaporizing ponds. Later on the dry sledges are scrapped and laid on the adjacent marshland, which is some 600-m from the tannery where farmers use it as soil conditioner.

The tannery has a chemical treatment plant (Plate 2) with an annual expense of 400 000 Birr. The treatment plant used to treat 2 million liters of water a day. The plant treats chemical, checks pH value, aerates to maintain the COD and BOD, before spilling to the lake. However, after the devaluation, is costed them 4 000 000 Birr. Therefore, they had abandoned the treatment operation. During Lake Truthing, it was observed that via a conal chemical and protein decomposition products are being dumped into the lake.

As per the data acquired from the Ministry of water Resources, water quality standard before the devaluation is exhibited on (Table 1).

For further refining the digital analysis best band combination to discriminate anomalous sectors was imperative. The Optimum Index Factor (OIF) and drawing spectral plots are some of the traditional methods. Recently, however, Divergence (D) is the best technique being employed by Remote Sensing specialists.

First and foremost, the computer must be trained to recognize patterns. To meet this requirement, statististical criteria, namely univirate statistics were used to allocate or assign the spectral distance threshold for groups of pixels with similar spectral values to grouped as ' classes' (signatures). For the purpose, a total of 15 signatures were identified for evaluation.

Divergence is the most customary method used to measure separability of classes. Apart from this, it is applied to predict the best three informative band combinations. Divergence 'D' analysis is a saturation transform, thus reduces dimensionality (number of correlated bands).

Transformed divergence (TD). In transformed divergence, values between 0 and 2000 are possible. Where 2000 shows the best (maximum) separability between class pairs. **TD** separability analysis, 'the weighted factor' though does not influence the **TD** equation, but influences the report of the best average and the best minimum separability. For Koka **'TD'** separability analysis, The default 1 as a weight factor was accepted and later was divided by the total number of classes, each having 0.067. As a result, the best average and minimum were attained (Table 2). The best averaged for Koka separability listing is 1998 and the best minimum is 1890. The class pairs having the least separability are 7 and 11.

As per the TD results, the best informative bands for the detection of anomalous polluted sectors of the lake are 2,3 and 7. It is well known that for limnetic studies, if the lake is transparent, TM Band 1 renders better information. However, in cloudy (turbid) lakes like Koka, Red band is chosen for analysis. In cloud waters the Red wavelength of the EMR (Electromagnetic Radiation) penetrates to a significant depth in the water column. Reflected (suspensoid of colloidal particles) and back scattered energy from particulate matter with a larger grain size are best recorded. In view Of this, Band 3 inclusion by TD is credible. The pseudocolor assignment (Plate 3) on bands 2,3 and 7 of Koka exhibits the grossly polluted northwestern sector of the lake. The cyan color at the littoral sector denotes that the Mojo tannery spills all its effluents to this sector. Moreover, the Mojo river which is a recipient of Addis Abeba's plumes eventually empties into the lake.

The two main approaches used in computer assisted image analysis and interpretation are batch mode, and interactive mod. For this digital analysis, the interactive mode was applied.

Image rectification. Although it is a geocoded data, the appropriate projection with the least isoscole is UTM. A total of 20 GCPs (Ground Control points) were taken from the assigned RMS (Root Mean Square) of 2. Despite its low frequency convolution, the absence of 'terraced' or 'stair stepped' effect and for its high spatial accuracy, the non-linear transformation was used for the 'rubber sheeting'. The 3rd order polynomial transformation had resulted in X RMS of 1.39 and Y RMS of 1.29, which is an acceptable threshold (see Table3).

To avoid the rhombic and dummy (fill pixel), a curbox output was prepared for the pseudo color assignment on the best three bands chosen by TD. Accordingly, the cyan color denotes the grossly polluted sector of Koka. Shades of cyan denote pollution mixing (Plate 3).

2.2 Proximal Sensing

Proximal Sensing. Is also a variety or Remote Sensing technique, but unlike a satellite platform, it is much nearer to the target. Proximal Sensing makes use of so called *non-imaging systems*. For the detection of physical pollution, a spectroradiometer scanning of the lake was done.

Non-imaging systems like spectroradiometer would show target reflectance in the form of profile for the subsequent parametric analysis. Scanning of the reservoir was taken at 14:28:49 during clear sky and at high sun angle for better illumination. Based on the scanned tabular data (Table 4) and reflectance curve (Fig.1.). The reflectance curve begins to fall at 402.1 nm reaches its dip with amplitude of 10 at 415 nm, which are all within the *blue wavelength* of the EMR. The curve shows a recovery from 420..3 to463.7 nm. From 466.5 nm to 711.5 nm the amplitude manifests a peak uniformity of 23, which corresponds to the *red wavelength*. To be more precise, the peak forms a small angle starting at 582 nm showing an increment of reflectance in the red *wavelength*, from 714 nm, the slope shows a nosedive and then forming a bowl shape in the reflective infrared region. In order to make the profile more discernible, it was exaggerated a

Point number	Image X pixel	X pixel residual	Image Y pixel	Y pixel residual
1	339.28	-0.1719 E 01	604.49	-0.5080 E + 00
2	297.01	-0.1987 E 01	157.72	0.7220 E + 00
3	220.01	-0.6827 E 00	374.13	0.1133 E + 01
4	116.56	-0.4382 E 00	539.04	0.3610 E - 01
5	457.37	0.2569 E 01	501.42	-0.1578 E - 01
6	518.74	-0.2612 E 00	328.97	-0.30225 E - 01
7	103.20	0.2012 E 00	266.92	-0.7737 E - 01
8	549.21	0.2205 E 00	164.28	-0.7183 I + 00
9	242.77	0.1772 E 00	336.82	-0.2177 E + 01
10	359.63	0.6464 E 00	68.38	-0.6204 E + 00
11	199.36	0.3635 E 00	682.92	-0.8283 E + 00
12	338.43	0.5521 E 00	312.35	-0.6488 E + 00
13	269.63	0.5535 E 00	657.63	0.6256 E + 00
14	511.28	0.2764 E 00	289.25	0.2490 E + 00
15	542.39	-0.2408 E 00	186.32	0.1315 E + 01
16	279.69	0.6927 E 00	219.77	0.7735 E + 00
17	393.98	0.9835 E 00	706.99	-0.2011 E - 01
18	424.99	-0.2013 E 00	624.60	0.3598 E + 01

XRMS error + 1.39701 Y RMS error = 1.29968
Total RMS error = 1.9089

Table (3) The third order polynomial transformation output.

Plate (3) cyan represents grossly polluted, while tints of cyan represent pollution mixing.

by multiplying factor of 8. The profile depicts a typical dissected plateau. A gorge in the blue region, a plateau in the red wavelength, then a depression in the reflective infrared region. If reflectance is the main optical property of the disperse phase, which do have a larger grain size, the result of the spectroradiometer ascertains that, the disperse phase in Koka is much larger than the optical wavelength..

To conclude, much of the information about the physical state of Lake Koka was achieved from the red wavelength region. Since blue wavelength irradiance could not penetrate cloudy water, a depression in the blue wavelength region indicates that the water is highly turbid. On the other hand red wavelength irradiance penetrating capability in cloudy lakes is high. Because of this, the spectral profile of Koka ascertains that, the lake is an engrosser of contaminants (both physical and chemical).

Findings

The synergetic approach of Remote and Proximal Sensing had resulted in the following findings.

· The applied Remote and Proximal Sensing synergetic approach has enabled the chemically and physically grossly polluted sectors of the lake.

· The potential application of grating spectroradiometer for water quality analysis on a boat platform was proven to be a handy technique to limnologists.

· The water samples taken from this anomalous sector were tested in the Addis Ababa University Biology Department's laboratory. It was confirmed that, it is grossly polluted. Sodium cation (N') which causes diffloculation of clay is absent. When irrigating a soil with high sodium (adjusting sodium cation Adsorption Ratio) is greater than 9 containing water, much of the exchange complex will be dominated by sodium. Hydrated sodium cation has much greater size than hydrated divalent cation (Ca' , Mg ') which are present in Koka. Due to its greater effective size, hydrated sodium cation increases the interlayer space of clay particles meaning destroying soil structure and hampering permeability of water by forming hard pan. The analysis had shown that there is but insignificant amount of sodium in Koka. Spillage of 250 chemicals some of which are toxic in due course of time would impart adverse effect on the lake's biota and agro-industrial development at the Lower Awash.

Recommendation

· Pollution has a great impact on the trophic chain within the lentic environment of Koka. Because primary production by phytoplankton in the lake requires better illumination, nutrient availability, CO_2 and temperature conditions. Since pollution deprives these necessary conditions, primary production would halt, therewith the second order in the trophic chain. Especially of economic interest zooplankton like fishes. The common fish species in Koka include 'Tilapia (Oreochromis niloticus, Barbus, Catfish, clarias'(Some limnological observation on two Ethiopian reservoirs, Melaku et al 1986). Chemical pollution lowers the Dissolved Oxygen (DO) thus inhibits the normal life of medium of the aquatic biota. In order to ward off further exacerbation of the deterioration of the water quality of Koka, primary and secondary treatment plants must resume abandoned works.

· From the point of the point of view of Remote Sensing digital analytical techniques, aquatic complexes, such as lakes alimented by chemical industrial effluents and high drift, on the image data pixels are called 'mixels'. In such a media non-linear, spectral and spatial enhancements of 5 x 5 matrix filter kernel improve the image discenibility.

· Remote sensor of non-imaging system like spectroradiometer scanning applied in such lake and the subsequent parametric analyses render useful limnetic information on water quality. In view of this, it is recommended that hydrologists and limnologists could apply the technique.

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Selective Liquid Membrane Extraction of Trace Quantities of Micropolutants in Enivronmental Waters: A Case Study Of Basic Herbicides in Southern Ethiopian Lakes

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Abstract

The liquid membrane extraction technique has been developed and applied to the selective enrichment of trace quantities symmetrical (*s*-) triazine herbicides in natural waters collected from Southern Ethiopian Lakes. In liquid membrane extraction, the uncharged *s*-triazine compounds from the flowing donor solution diffuse through a porous poly (tetrafluoroethylene) (PTFE) membrane, containing a water immiscilbe organic solvent. The compounds are then transported through the hydrophobic membrane and there irreversibly trapped in the stagnant acidic acceptor phase since they become protonated.

There are a number of agricultural fields in the Southern Ethiopian region, where herbicides are periodically applied, in close proximity to the lakes. Thus, the lake waters certainly contain considerable quantities of these residues and their degradation products. Water samples, collected three times after the herbicide application, were pre-treated before dissolving the phosphate salts to obtain a buffer of neutral pH. Sample extraction of the contaminated waters was performed at the donor flow rate of 5.0 mL/min. Low quantities of atrazine and terbutryn, ranging in concentration from 0.02 to 0.05 mg/L were identified in Awassa and Chamo Lakes. The identity of the compounds was also confirmed using a diode array detector.

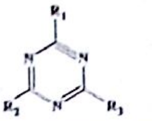
The quantities of herbicides estimated in the lake waters were lower than the maximum admissible level given by some authorities, e.g., the European Union. It may also be important to closely investigate the seasonal variation of the residues in these waters by performing certain monitoring programme, taking the sampling technique and time, collection sites and depth and other physical and meteorological parameters into consideration to draw more general conclusion concerning the level of toxicity of these pollutants in these lakes.

Introduction

The use of chemical pesticides for different purposes such as forestry management, railway, protection against infections with parasites transmitted to humans by insects, and against insects and weeds in agriculture, is very common all over the world today. Considering pesticide use for agricultural purposes, it has been a known fact that their effective use has improved the quality and quantity of food, and advances in pesticide technology have increased the ability to sustain and improve the health and well-being of the ever-growing human population. Unfortunately, these chemicals are potential pollutants having deleterious effects on human health and the environment [1, 2] when their concentrations are higher than certain limits.

On the other hand, their extensive use for various purposes, in particular in agriculture, has led to increasing interest for their determination in environmental studies. These extensive uses with high application rates, also cause the residues of these compounds and their major degradation products to eventually be transported to surface water, ground and lake waters, and rivers by different mechanisms such as non-point source run-off, ground water discharge or atmospheric deposition [3].

One class of these herbicides, currently popular on worldwide scale for selective pre- and post-emergence control of broad-leaved and grassy weeds in corn, soyabeans and other field crops including green vegetables are the symmetrical (*s*-) triazines. These compounds were synthesized about forty years ago by J. R. Geigy, in Switzerland. They are commercialized in three different structural varieties whose chemical characteristics are primarily determined by the substituents in position 2, Table 1. They are among the classes of chemical pollutants more heavily monitored, and detected in environmental waters usually at levels higher than the maximum amount allowed [4-5]. According to the current European Union (EU) directives, for example, the maximum admissible concentration (MAC) in drinking water is limited to 0.1 mg/L for single pesticides and 0.5 mg/L for the sum of pesticides including toxic transformation products [4, 6-7]. This poses a strong demand for development of new techniques to extract large volumes of water samples containing trace quantities of micropollutants. Furthermore, in the effort to develop analytical methodologies capable of determining potential pollutants in water samples, minimizing the effects of matrix interferences by



Compound common name	Substituents			Solubility in water (ppm) (20-25°C)	Melting point, °C	pK_a value	Absorption Maxima, nm		Density, g/cm³
	R_1	R_2	R_3				λ_1	λ_2	
Simazine	Cl	NHC_2H_5	NHC_2H_5	5	225-227	1.65	222	263	1.302
Atratone	OCH_3	NHC_2H_5	$NHCH(CH_3)_2$	1650	-	4.20	217	-	-
Atrazine	Cl	NHC_2H_5	$NHCH(CH_3)_2$	33	175-177	1.68	222	263	1.187
Prometone	OCH_3	$NHCH(CH_3)_2$	$NHCH(CH_3)_2$	750	91-92	4.20	219	-	1.088
Propazine	Cl	$NHCH(CH_3)_2$	$NHCH(CH_3)_2$	8.6	212-214	1.85	221	268	1.162
Terbuthylazine	Cl	NHC_2H_5	$NHC(CH_3)_3$	8.5	177-179	1.94	223	263	1.188
Prometryn	SCH_3	$NHCH(CH_3)_2$	$NHCH(CH_3)_2$	48	118-120	4.10	223	-	1.150
Terbutryn	SCH_3	NHC_2H_5	$NHC(CH_3)_3$	58	104-105	4.30	223	-	1.115

Table 1 Substituents and selected physical constants of the s-triazine herbicides under study[2,15,22-23]

Compound	E at varied molar concentration of sulphuric acid				
Common name	0.02 M	0.05 M	0.10 M	0.50 M	1.0 M
Simazine	0.041 (0.12)	0.074 (0.17)	0.105 (0.57)	0.339 (1.21)	0.442 (0.36)
Atratone	0.595 (1.31)	0.658 (0.41)	0.662 (1.90)	0.667 (1.70)	0.631 (0.57)
Atrazine	0.078 (0.10)	0.140 (0.32)	0.192 (0.80)	0.427 (1.52)	0.501 (0.10)
Prometone	0.685 (0.26)	0.745 (0.73)	0.746 (2.30)	0.750 (1.76)	0.703 (0.85)
Propazine	0.084 (1.62)	0.186 (0.27)	0.262 (1.08)	0.518 (1.60)	0.549 (0.99)
Terbuthylazine	0.090 (2.36)	0.217 (0.78)	0.321 (2.18)	0.539 (1.54)	0.554 (0.71)
Prometryn	0.711 (1.72)	0.776 (0.12)	0.768 (1.74)	0.763 (1.86)	0.692 (1.49)
Terbutryn	0.703 (1.01)	0.753 (0.90)	0.780 (3.78)	0.717 (1.40)	0.632 (0.28)

Table 2 Effect of the acceptor P^H on by changing the concentration of sulphuric acid, with di-n-hexylether as a membrane solvent. Numbers in bracket are relative standard deviation for triplicate extractions.

selectively extracting the target compounds, should be given foremost attention [8].

Various sample preparation and selective enrichment methods for *s*-triazine herbicides from environmental waters have been developed. The most commonly used ones today including liquid-liquid extraction (LLE), solid-phase extraction (SPE), solid-phase microextraction (SPME), supercritical fluid extraction (SFE), and microwave assisted extraction (MAE) were recently reviewed [9-10].

An alternative sample preparation method using a hydrophobic membrane, separating phases, has also been developed and being used for more than a decade for pre-treatment and selective enrichment of various samples containing complex matrices [11]. The principle of this technique, called supported liquid membrane (SLM) extraction, is based on selective extraction of the analyte molecules from the flowing aqueous donor phase to the hydrophobic membrane followed by re-extraction into the second aqueous phase filled with appropriate solution for irreversibly trapping the extracted analytes. SLM was found suitable for selective extraction and enrichment of polar compounds, such as organic acids and bases, charged compounds and metal ions [12].

The use of liquid membrane extraction for selectively extracting all classes of the *s*-triazine herbicides from environmental waters has been developed [13-15]. In a similar application Martinez *et. al* [16] have used a silicon rubber membranes for extraction of this class of herbicides from oil samples followed by flow injection analysis (FIA) or high performance liquid chromatographic (HPLC) in an on-line mode. In the work presented here, a method for extracting all classes of the triazines in a complex mixture has been employed to extract the residues of *s*-triazines in natural water samples collected from Awassa, Chamo and Abbaya Lakes, found in the rift valley of Southern Ethiopia [17]. Triazine herbicides have been in use extensively for long time in agricultural farms situated in close proximity to these lakes.

Fig. 1 Membrane separator: (A) aluminum backup; (B) PTFE block with grooves like Archimedean spiral; and (C) porous PTFE membrane with polyethylene backing

Materials and Methods

Standard and Working Solutions. 100 mg/L stock solutions of all the *s*-triazine herbicides studied, Table 1, were prepared in acetonitrile. Solutions of the phosphate buffer, pH 7.0, were prepared from $NaH_2PO_4.H_2O$ and $Na_2HPO_4.2H_2O$ [18].

Standard solutions containing the *s*-triazine herbicides of interest were obtained by diluting the stock solution in reagent water. A series of solutions for calibration, in the concentration range of 0.1 to 2.0 mg/L, at five points, were prepared every week from the 10 mg/L standard solution. The working aqueous solution of 0.5 mg/L was obtained from the stock solution in acetonitrile. All stock, standard, aqueous and extracted solutions were stored at 0°C when not in use for analysis.

Analytical-grade organic solvents were utilized for immobilizing into the membrane support, and the ones employed in this work were di-*n*-hexylether and *n*-undecane. Acetonitrile of HPLC grade was used both for mobile phase and for dissolving the standards. Aqueous solution of 0.05 M sodium acetate was mixed with the mobile phase to be used in an isocratic mode. Most of the chemicals used were of analytical-reagent grade and purchased from Merck, while the standards of the herbicides were from Promochem (Wesel, Germany). All solutions were prepared from

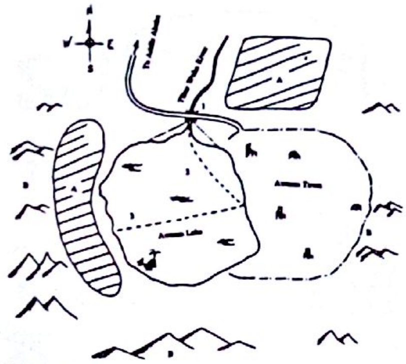


Fig. 2 Sample collection site at Awassa Lake. A – Agricultural fields, B – Hills surrounding the lake. Numbers represent collection point (1) or approximate line followed for sample collection (2 and 3). See also text.

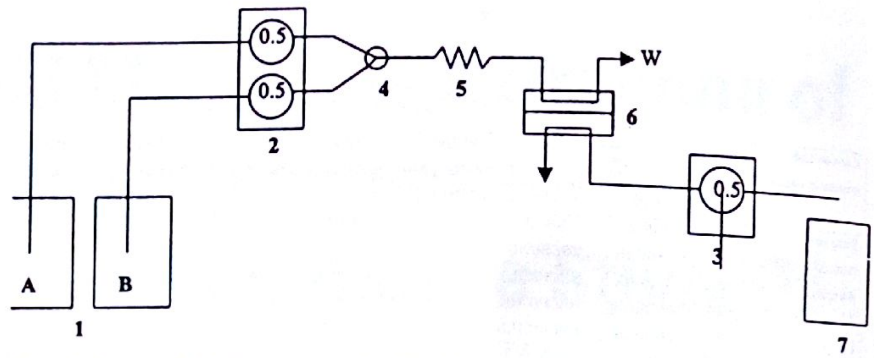


Fig. 3 Set-up of the flow system for liquid membrane extraction: (1) containers for sample solution (A) and donor buffer (B); (2) and (3) peristaltic pumps for the donor and acceptor channels, respectively; (4) PTFE tee connection; (5) mixing coil; (6) membrane extraction unit; (7) container for acidic acceptor solution; and (W) waste.

analytical-grade reagents in high purity water obtained from a Milli Q-RO4 unit (Millipore, Bedford, MA, USA).

Experimental Set-up. The membrane holder consists of two circular polytetrafluoroethylene (PTFE) blocks, Fig. 1, with a diameter of 120 mm and a thickness of 8 mm, and with machined grooves like Archimedean spiral (depth 0.25 mm, width 1.5 mm and length 250 mm giving a total volume of ca. 0.95 mL). The soaked liquid membrane, when placed in the membrane separator, creates two separate channels. The rough side of the liquid membrane faces the donor channel through which the extraction sample solutions percolate. It is also equipped with an O-ring, outside the grooves, for preventing the leakage of the sample solution. The second compartment is the acceptor channel where extracted analyte solutions will get enriched. Both sides of the membrane holder were backed with aluminum blocks of 6 mm thickness, in which threads for the clamping screws were machined to make the assembly stable.

The liquid membrane support was porous PTFE, Millipore FG, with an average pore size of 0.2 mm, total thickness of 175 mm of which 115 mm is polyethylene backing, and a porosity of 70%. The liquid membrane was prepared by immersing the membrane support in the organic solvent to be immobilized, typically for a period of 30 min.

Sample solutions prepared for extraction were transferred to the membrane system with peristaltic pump using acid-resistant tubing with internal diameter of 2-mm both for the donor and acceptor channels. The sample and buffer solutions were pumped separately and merged in a PTFE tee connection at an angle of 60°. Further mixing was also performed in a coil of 1 m length. The various parts of the flow system were connected with PTFE tubing and flange-free screw fittings.

Water Sampling from Southern Ethiopian Lakes. Lake water samples were collected three times after the herbicide application from Awassa Lake (270 km), and Chamo and Abbaya Lakes (500 km south of the capital, Addis Ababa). The first sampling was performed in August 1998, followed by November and finally in March 1999.
To obtain representative samples, a grab sampling method, was employed during all the sampling periods. In all cases, three variations of the collection areas were chosen. (An example of the sample collection from Awassa Lake will be considered, since similar procedures have also been followed for the rest of the sites, Fig. 2). Location one is the entrance point of the tributary river called Tikur Wuha (Black Water in the local language). Sample collection for the second location covers the area from entrance of the river to about half way the length of the lake on the side of Awassa town (eastern side). Final location starts from end of the second sampling, and across the center of the water body to the other side (to the west). To obtain composite samples, particularly in locations 2 and 3, about 200 mL of the lake water was drawn each time at a distance of about 10 m, for a minimum of 2 and 3 h, in locations 2 and 3, respectively. In location 1, sample was taken from a point of the river entrance to the lake. Lake waters were collected in polyethylene containers and brought to the laboratory in less than 48 h, and kept in the cold room below 5°C.

Before liquid membrane extraction, the lake water samples were all filtered to remove the suspended impurities and particulate matters. The filtered samples were then kept in the refrigerator when they were not extracted immediately. All water samples from Chamo Lake were extracted without storing for more than a day, which otherwise require re-filtering to make sure that the algae have been removed. All extractions have been carried out at ambient temperature, 20 ± 2°C.

Membrane Enrichment. The sample containing the analytes of interest and the phosphate buffer (pH 7.0) were delivered to the liquid membrane system at a flow rate of 1.0 mL/min, Fig. 3. Prior to the sample extraction, the acceptor channel was filled with acidic solution, 0.1, [14-15] 0.5 or 1.0 M [17], at a flow rate ranging from 0.2 to 0.5 mL/min, and kept stagnant. This was followed by pumping of the donor channel with the standard solution for 20 min, and for 10 more minutes with pure buffer solution to wash the flow tubing and allow all the sample solutions to pass through the liquid membrane. The system was then left to stand for ten minutes to give sufficient time for the analytes to diffuse to the acceptor acid solution where they are irreversibly trapped. At the end of ten minutes waiting time, the content of the acceptor channel was transferred to a 10-mL graduated glass tube, by displacing with the respective acceptor acid solution used in the system. The resulting extracts were adjusted to pH 7.0 with diluted solution of sodium hydroxide.

For lake waters, prior to extraction the sodium salts of phosphate were dissolved in the filtered water samples to obtain pH 7.0 of the sample solution. One to three liters of the processed samples were delivered to the liquid membrane, containing the appropriate membrane solvent, for extraction at a flow rate of 5.0 mL/min. When di-*n*-hexylether was used the concentration of sulphuric acid in the acceptor was 0.5 M [13] while it was 0.1 M [14-15] for *n*-undecane membrane solvent. When sample pumping was completed, the donor channel was rinsed for 30 min with the donor buffer at the same flow rate, which was followed by 30 min standing of the membrane module. 3.0 mL of the enriched sample was transferred to a 10-mL graduated tube by purging the acceptor with the acidic solution, and pH of the enriched solution was immediately adjusted using about 0.5 mL of 6 M and 0.2 mL of 3 M NaOH for the extracts from di-*n*-hexylether and *n*-undecane membrane solvents, respectively.

Chromatographic Separation Systems. Analysis of the *s*-triazine herbicide compounds was performed using the high performance liquid chromatographic, HPLC, system, incorporating of a high pressure pump (Spectra Physics, San Jose, CA, USA) equipped with an autosampler (Waters, WISP Model 710B, Milford, MA, USA). For isocratic reversed-phase separation of the herbicide compounds, a mobile phase composed of 50% 0.05 M sodium acetate was utilized. In all cases, the pH was adjusted to 7.0 with 0.5 M sulphuric acid, and was then degassed by bubbling helium for at least 10 min. The mobile phase was also allowed to pass through a vacuum degasser before entering the pumping system. For rinsing of the loop of the autosampler, helium-degassed solution of 50% acetonitrile in reagent water was employed. 20 or 25 mL aliquot of the enriched analyte samples were introduced to the HPLC system, except when lower concentrations, below 5 mg/L were extracted, in which cases 50 mL were injected.

Separation of the compounds was performed on a C18 analytical column (Techsphere 5ODS 250 mm x 4.6 µm I.D.; HPLC Technology, Macclesfield, Cheshire, UK) connected to the variable wavelength UV-VIS detector (Model 757, Kartos Analytical Instruments, Ramsay, NJ, USA). The detector signals were collected and handled with a personal computer using a JCL 6000 Chromatographic Data System (Jones Chromatography Ltd., Hengoed, Mid-Glamorgan, UK). All analyses were carried out at the mobile phase flow rate of 1.0 mL/min and signals, based on the peak height, were monitored at the wavelength 220 nm.

For confirmation of the identity of the *s*-triazine compounds, extracted from lake waters, a photo diode array detector (PDA 996, Waters) was used. Spectra of the compounds identified, i.e., atrazine and terbutryn, at 210 - 300 nm from the detector were monitored using a Millennium 2.15 (Waters) chromatographic computer system.

Determination of the Extraction Efficiency. A series of aqueous sample solutions in the concentration range 0.1-2.0 mg/L was prepared from standard solution in acetonitrile, and introduced to the chromatographic system with each set of extracts. Calibration graphs for the compounds of interest were constructed based on triplicate injections. They all gave linear correlation coefficients of 0.9998 or better with insignificant intercepts at 95% confidence level. The corresponding concentrations of the extracted and enriched samples were evaluated using the calibration graph.

Results And Discussion

The SLM extraction may be considered as a three-phase extraction system, with an organic phase sandwiched between two aqueous phases. The process of analyte enrichment is therefore the combination of extraction into the organic solvent followed by a back-extraction into the second aqueous phase [12]. The theories applied to the mass transfer process in SLM extraction have been described elsewhere [19-20]. In general, the rate at which analyte molecules are transported may be explained by the following two conditions. (i) Donor-controlled extraction - with this process the mass transfer is limited by the diffusion in the donor phase and donor flow conditions, and (ii) membrane-controlled extraction - in this case the rate-limiting step is the diffusion of the analytes through the membrane.

With donor-controlled extractions the distribution coefficients, K_p, is larger than 10, while $K_p < 1$ with membrane-controlled extractions. It should be noted that the value of the distribution coefficient has no significant effect on the extraction efficiency as long as it is reasonably large.

Liquid Membrane Extraction Parameters

(i) Extraction Efficiency. The extraction efficiency, E, is the fraction of the analytes extracted from the flowing donor phase into the stagnant acceptor phase [21, 22], and E is calculated using the following equation:

$$E = \frac{n_a}{n_d} = \frac{C_a V_a}{C_d V_d}$$

Where n_a and n_d are the number of moles of solutes collected in the acceptor solution and entering the extraction system, respectively. C_a is the concentration of the analytes enriched in the acceptor, V_a is the volume, after pH adjustment, of the enriched samples collected from the acceptor phase. C_d is the concentration of the aqueous sample entering the donor phase and V_d is the total volume of the sample passing the donor channel.

E is the measure of the rate of mass transfer through the membrane, and at specified extraction time, flow rate, membrane composition and ionic strength it is constant. In earlier works on extraction of *s*-triazines using liquid membrane methodology [14-16], it has been observed that extraction is fairly complete, and amounts of molecules quantified in blank extraction varied only from 0.5 to 5.0 % of the extracted sample. The mass transfer was also examined [14] by allowing the extraction system to stand still to give time to the molecules retained in the membrane to diffuse. The amount of analytes quantified in a series of experiments was below the uncertainity of the measurement. Thus, it can be concluded that the mass transfer of these compounds is controlled only by their diffusion to the membrane (donor controlled condition [12]) and the process of analyte transfer seems faster, i.e., complete in 20 min.

(ii) Membrane solvent. Both di-*n*-hexylether and *n*-undecane have been reported for extraction of *s*-triazine herbicides from environmental waters. The fairly polar compounds like chloro-*s*-triazines [13] and methyoxy-*s*-triazines [15] have been well extracted in the more polar solvent, di-*n*-hexylether. In the present work both membrane solvents have been employed since more than one class of *s*-triazines were applied in the agricultural fields in the area of the study. The membrane solvents were used under different pH conditions in the acceptor solution; *viz.*, 0.1 M sulphuric acid for *n*-undecane and 0.5 M for di-*n*-hexylether membrane solvents. The results for 20 minutes extraction of 0.5 mg/L of the compounds at donor flow rate of 1.0 mL/min are given in Tables 2 and 3. As it can be seen from these results, *s*-triazine compounds are well enriched using both membrane solvents, except for the chloro-*s*-triazines whose enrichment seem to depend mainly on the concentration of the acceptor acid. One important observation is that when acid concentration was increased beyond 0.5 M, the efficiency starts declining gradually which may be due to analyte degradation [23].

(iii) Effect of the donor and acceptor pH on E. One of the most important factors governing the SLM extraction of *s*-triazines is the acceptor pH.

The influence of the donor pH on the extraction efficiency of the *s*-triazine herbicides is not very crucial so far as the pH of the donor solution is kept 2 pH units more than the highest pK_a of the compounds [20], to facilitate their dissolution in the membrane. E for *s*-triazines is not affected when the donor pH is between 6.0 – 8.0 [14-15]. Thus, using the phosphate buffer, ionic strength in the final solution is 0.2 [18], the donor pH was adjusted to 7.0, both in the standard as well as in the field samples.

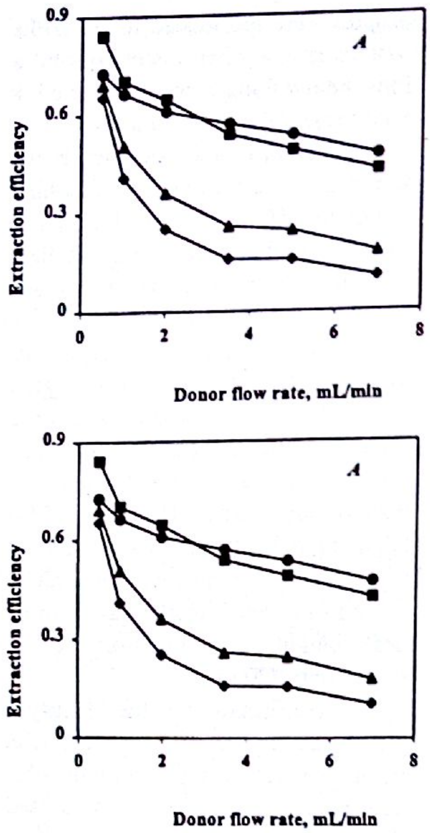


Fig. 4 Donor flow rate dependence of E for 20 min extraction of 0.5 mg/L of each s-*triazine compounds. (A) Di-*n-*hexylether membrane solvent and acceptor acid concentration of 0.5 M; symbols: (w) - atrazine, (n) - prometone, (?) - propazine and (l) - terbutryn. (B)* n-*Undecane membrane solvent and acceptor acid concentration of 0.1 M; symbols: (?) - atratone, (˜) - prometone, (?) - propazine, and (¡) - terbutryn.*

The extent of extraction of the *s*-triazine is rather more dependent on the acceptor pH. Using dilute aqueous sulphuric acid solution, this effect was controlled so as to obtain maximum extraction efficiency by minimizing the possibility of degradation of the compounds. Their hydrolysis in acidic solutions to yield the hydroxy derivatives has been reported [23]. When the pH of the extracted solution was adjusted to 7.0, immediately after the extract collection, the possibility of degradation is less likely. Therefore, it is very important to note how long the extracted sample is left in acidic solution to estimate the extraction efficiency. The general extraction behaviour is given in Tables 2 and 3. For example, Propazine, having lower pK_a value, as all other chloro-*s*-triazines, is better extracted in higher acidic conditions. Thus, in general, the optimum acidic condition in the acceptor phase follows the nature of the membrane solvent, and whenever possible concentrations of acids less than 0.5 M should be used unless the extract is collected in a preprocessed buffer whose pH is controlled.

Donor flow rate. Extraction efficiencies close to 100% can be achieved if the donor flow rate is low enough. However, when large sample volumes are available, e.g., natural water, extractions at higher flow rate are preferred since the enrichment of the analytes per unit time increases. The application of such experiment is useful for compounds having large partition coefficient between the liquid membrane and the aqueous donor phase. As it has also been shown in Figs. 4a and 4b, the decrease in extraction efficiency for *s*-triazine compounds is gradual and thus the

Compound common name	E_e for 0.5 µg/L in one liter		E_e for 0.1 µg/L in 3 liters	
	Di-*n*-hexylether	*n*-Undecane	Di-*n*-hexylether	*n*-Undecane
Simazine	6.6	3.2	47	48
Atratone	170	95	327	323
Atrazine	97	29	454	467
Prometone	205	158	443	439
Propazine	6.7	2.2	10.7	nd
Terbuthylazine	18.2	16.6	78	nd
Prometryn	233	179	472	477
Terbutryn	287	225	699	740

nd – not detected

Table 4. Enrichment factors, E_e, for extraction of the standard samples spiked in reagent water. All samples were extracted at the donor flow rate of 5.0 mL/min, and the values are mean of four extractions.

Compound common name	LOD, ng/L, for extraction of one liter standard solution		LOD, ng/L, for extraction of three liters standard solution	
	Di-n-hexylether	n-Undecane	Di-n-hexylether	n-Undecane
Simazine	152	317	32	30
Atratone	5.9	10.5	3.4	3.4
Atrazine	10.3	34.6	2.3	2.2
Prometone	4.9	6.3	2.5	2.5
Propazine	207	*nd*	86	*nd*
Terbuthylazine	55	60.4	20	*nd*
Prometryn	4.3	5.6	2.3	2.2
Terbutryn	3.5	4.4	1.5	1.4

nd – not detected

Table 5. Limit of detection, LOD, for extraction of various volumes of the standard solutions at concentration levels of 0.5 µg/L and 0.1 µg/L, and donor flow rate of 5.0 mL/min.

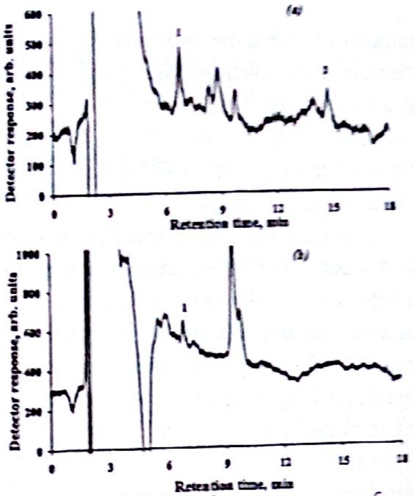


Fig. 5 HPLC-UV chromatograms for the extracts of lake water samples: extraction conditions: donor flow rate – 5.0 mL/min; membrane solvent – di-n-hexylether; and sample extraction time – ten hours. Peaks (1) atrazine, and (2) terbutryn. Chromatograms for (a) extract from Awassa Lake, and (b) extract from Chamo Lake.

accumulation per unit time is high. The extraction efficiency decreases very fast for propazine as the donor flow rate incerases in the *n*-undecane membrane solvent, Fig. 4b. This is not unexpected observation since all the chloro-*s*-triazines [13] with lower pK_a values may have better dissolution in the more polar membrane solvent, di-*n*-hexylether, Fig. 4a.

At the expense of sample volume and time, high analyte enrichment can best be achieved with liquid membrane extraction. Since breakthrough doesn't occur, analytes can be well accumulated to bring their concentration to a detectable level by conventional detection systems. The main problem associated with increased donor flow rate is the decrease in the life time of the membrane, which may probably be due to dissolution of membrane liquid into the flowing large volume aqueous sample [15]. In the present work, for extraction of *s*-triazine compounds from lake waters, donor flow rate of 5.0 mL/min was chosen, which is not very high to remove the membrane liquid in few extractions. Analytes of very low concentration in the lake water have been enriched and quantified. About 20 extractions can be done before the membrane is leaking when one litre water sample is extracted at this flow rate.

Enrichment Factor. The extent to which the extracted molecules are accumulated in the acceptor compartment has been studied at donor flow rate of 5.0 mL/min, using both membrane solvents. First, one liter spiked standard solution of 0.5 mg/L, with respect to all the *s*-triazine compounds, was extracted. In another series of experiments three liters of spiked sample solutions, whose concentrations were 0.1 mg/L were extracted in the same manner to investigate the enrichment of the compounds at trace levels. In both cases, enrichment factor, E_e, was evaluated using the following equation, Table 4.

$$E_e = \frac{C_a}{C_d} \qquad (2)$$

Where C_a is the concentration of the enriched sample, and C_d is that of the solution entering the donor channel to be extracted. The results obtained are given in Table 4. This may proves that trace analysis with SLM technique for *s*-triazine herbicides is successful, and accumulation of the compounds seems independent of the concentration in the original sample, regardless of the sample origin.

Applications. The liquid membrane extraction methodology was applied for extraction of samples of natural waters collected from Southern Ethiopian Lakes; *viz.*, Awassa, Chamo and Abbaya. In this region of the country there is an extensive use of agrochemicals, including herbicides and insecticides, to various farms sprayed by farm workers and air plane. One of the pesticides most frequently used as an active ingredient is the *s*-triazine family, the formulation of which is prepared alone or in combination with other pesticides. For example, atrazine is mixed with alachlor, metolachlor and bentazone in various proportions [24-25].

*Mean ± 95% confidence level for the mean values indicated in brackets.

These agricultural fields are situated in close proximity to the lakes selected for the present study. There is a high possibility for the residues of these compounds to get their ways to the lakes by surface runoff, wind, cattle hooves etc. Water bodies of the recipient lakes will thus be contaminated and may contain considerable quantity of these residues.

Water samples collected from these lakes were extracted, after some pre-processing steps including filtration and treatment with buffer. The extraction process follows the same procedure as the extraction of trace level standard extraction for determination of the detection limit. The amounts of *s*-triazines in these lakes have been estimated using the extraction efficiencies at 5.0 mL/min,

s-Triazine compound	Extract from Awassa Lake*		Extract from Chamo Lake*	
	DHE	UDC	DHE	UDC
Atrazine	6.6 ± 0.7 (6)	5.1 ± 2.3 (4)	5.3 ± 2.1 (3)	2.6 ± 1.9 (3)
Terbutryn	7.0 ± 3.0 (5)	8.1 ± 4.7 (4)	-	-

*Mean ± 95% confidence level for the mean values indicated in brackets.

*Table 6. Concentrations, in µg/L, of atrazine and terbutryn in Awassa and Chamo Lakes, applying SLM extraction at the donor flow rate of 5.0 mL/min. DHE stands ofr di-*n*-hexylether and UDC for* n*-undecane.*

equation 1. Atrazine and terbutryn were identified in Awassa Lake, while only atrazine could been found in the enriched extracts of Chamo Lake, Table 6. None of them could be identified in the extracts from Abbaya Lake.

The quantities of atrazine estimated in Awassa Lake by liquid membrane extraction when di-*n*-hexylether was used as a membrane solvent were about 0.05 mg/L and 0.04 mg/L in *n*-undecane membrane solvent. Slightly lesser quantities of atrazine were found in Chamo Lake; 0.04 mg/L with di-*n*-hexylether and 0.02 mg/L with *n*-undeacne membrane solvent. Terbutryn was also identified and quantified in Awassa Lake, and the quantities estimated were 0.03 mg/L and 0.04 mg/L in di-*n*-hexylether and *n*-undecane membrane solvents, respectively. The spectra of the extracts for both compounds were compared with that for the standard, and they were found to be identical [17]. The chromatograms for the extracts of lake water samples enriched using supported liquid membrane are given in Fig. 5.

A closer examination of the seasonal variation of the herbicides distribution in Awassa lake indicated that extracts from all sites were not always containing the residues. The samples collected from the bulk of the lake contained both atrazine and terbutryn, while only atrazine could be identified in the samples taken from the point of entrance of the tributary river. None of them could be observed in the sample extracts from the shore sides. This may be due to the insufficient lateral and vertical mixing of the lake water at the bank as has also been noted by Akerblom [26]. Moreover, in none of the extracts from the third collection were the herbicides identified. Probably, in due time they have been either degraded, adsorbed to the plants or settled down by forming complexes with various substances e.g., metals.

It Can thus be generalized that sampling, sample collection time and collection sites are very important variables when environmental monitoring experiments are to be carried out, for analysis of herbicide residues in these areas.

Conclusions

The possibility of applications of the supported liquid membrane technique for extraction of the natural water samples containing complex matrices has been presented. The results obtained from lake water extraction confirmed the presence of the herbicide compounds, and these were lower in concentration than the admissible limits given by some authorities, e.g., EU directives [6]. It may also be important to examine the seasonal variation of these parent compounds by performing certain monitoring programme, taking the sampling technique and time, collection sites and depth, and other physical parameters into consideration.

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Detecting The Transgression of Lake Beseka By Implementing Remote Sensing – GIS Techniques.

Asfaw Demeke Ethiopian Mapping Authority Addis Ababa

1. Introduction

The overall aim of the study is to map changes pertaining to lake Beseka and to assess the impacts of lake's surface area expansion by employing remote sensing and geographical information systems (GIS) techniques. The analyses have been carried out by processing multi-date remotely sensed data and ancillary source materials. The drastic changes observed over Lake Beseka is one of the major reasons initiated me to study the area. Because this big issue is in existence for more than 25 years without reliable solution so far.

Information is about creating and understanding options. Information about the environment is important for resources management and planning. The definition of environmental information and its value are therefore determined by socio-cultural and technological context. Remote sensing is a highly effective method of conducting resource surveys, environmental monitoring and mapping.

Remote Sensing - is the measurement or acquisition of data about an object or scene by a satellite or other instrument above or far from the object. Aerial photography, satellite imagery, and radar are all forms of remote sensing.

People are busy in seeking new ways in which to gather more environmental information and make use of it. From 1960s onwards, satellites have greatly enhanced our real-time spatial reach. Satellite remote sensing from platforms as far as thousands of kilometres from the earth, gather information from visible and invisible wavelengths to our eyes. Thus, it increases both spatial reach and what we might call 'spectral reach' by gathering information from the Infrared (IR) parts of the electromagnetic spectrum. These spatial and spectral reaches are authorized to acquire global biosphere images.

The use of satellites in providing high resolution images has driven & broadened the development of remote sensing applications in the field of:

· Coastal Oceans surveys (e.g. continental shelf monitoring, sea ice);

· Observing environmental problem (e.g. water pollution, oil spills, thermal pollution etc.).

· Water Resources Management (e.g. soil moisture, snow/ice surveys);

· Monitoring (change detection) dynamic phenomena (e.g. seasonal, temporal and other global /local changes);

· Agricultural monitoring (e.g. inventory, yield prediction);

· Land-use monitoring (e.g. classification and mapping);

2. Bacground

Lake Beseka is located at a closer distance to the Metehara sugar plantation, river Awash, Metehara town and sporadic villages in the vicinity. Currently, the main road and the longest & most important railway line in Ethiopia are under high risk than ever before. These essential transport arteries connect Ethiopia with abroad, and similarly many important towns in the eastern regions with the heart of the country. These transport lines have been and are suffering from continuing lake surface area expansion and level rise. Thus, the Railway Road Authority and Water Authority were busy and alert to protect the infrastructures from possible damages. All local mass media have been going in frequently for this very sensational issue. The main targets of the study are, firstly, to identify and analyze the causal inducing factors of the lake's transgression. Secondly, to sensitize the minds of the concerned institutes and the community around the lake basin. Thirdly, to forward meliorative measures which if properly implemented would ward off the negative trends of the ecosystem. This would help to reinstate the ecological status of the area.

3. The Study Area

The study area covers the Lake Beseka's base and juxtapose lands. Lake Beseka is located in the river Awash basin. It is located in East Showa zone of Oromya National Regional State between 39°45" to 40°00'E and 08°45'to 09°00' N (Ethiopia). See (Figure 1).

Faults are one of the main geological structures in the area, mainly, surrounding Lake Beseka.

Regarding the drainage system of the area, Lake Beseka occupies a significant portion of the study area. However, drainage network is very limited.

4. Objective

Based on the fore-mentioned factors and related problems the following approaches have been developing:

* To identify and analyze the surface area expansion of lake Beseka by implementing remote sensing and GIS methods, and using time-series data;
* To forward meliorative measures which if properly implemented would ward off the negative trends of the eco-

system; and

* To sensitize the minds of the prefectural authorities and the community around the lake basin.

5. Method

To reveal changes pertaining to the lake Beseka various datasets obtained from different sources were needed. Organizing these data was one of the difficulties encountered the work process. After collecting the necessary data bringing them into an agreement was another challenge. Because they were in different formats and different scales. However, thanks to the adventure of science, GIS and remote sensing, which enabled solve successfully the problems by implementing their methods. GIS renders a great opportunity to build database, to handle and manage such a large volume of natural and other data. Environmental change study is one of the major fields of applied remote sensing and Geographical Information Systems (GIS). The methodology for detecting lake dynamics involved the following stages: (a) data extraction, (b) data integration, (c) data analysis and (d) production of the final outputs.

6. Data Processing

For this study, one aerial photograph of 1957, two sets of Landsat-MSS imageries acquired in 1973 & 1979, and SPOT-XS image of 1991were used. Attributes related to surface hydrology, to geology and soil information were obtained from different topographic maps in different scales and dates.

Timely and reliable monitoring is a prerequisite to effective management of the environment. The lack of up-to-date information hinders the process of monitoring and maintaining of the ecosystem. Managers of environmental protection, planners, and many other decision-makers urgently need updated, quickly and cheaply produced maps.

7. Change Detection

All features either natural or cultural are dynamic always. The particular value of space based measurement lies in a range of repetitive observations which makes possible, the detection of temporal changes. Experience with satellite-derived data indicates that any nation can make use of such data in different fields for development purposes. The ability to compare digital data recorded by the same sensor for an area at different times will transform our understanding of how the earth's surface is changing.

Research extending back to mid - 1950s has revealed that Lake Beseka is in a non- stop dynamism in its morphometric indices. These are mainly the increment in its volume, depth (level rise), and spatial expansion. Since 1957 to 1991, its surface area increased 11- fold. In 1957 its area was about 3.0 sq. km and it had grown to 34.34 km² in 1991. From this it is clear that, the total surface area expansion of the lake from 1957 till the end of 1991 has accounted for 31.34 sq. km. Figure (2) pinpoints the spatial locations where the boundary changes have taken place since 1957 to 1991. This map clearly displays the constituent components of gains in the lake area. This dynamic change has drawn my attention to select the area for my study. As the results of the data analyses reveal that the lake expansion is at a steady rate even today.

8. The Causal Factors of The Lake's Area Expansion and Level Rise

The application of multi-stage and multi-temporal remote sensing and GIS techniques helped to detect noticeable changes occurred on the lake Beseka. Almost all observed changes pertaining to the lake started after the establishment of Metehara sugar plantation, which dates to (1969/1970). However, this is a curious coincidence. Because, according to later analyses channel spillage of excess irrigation water to the lake cannot be considered as one of the major causes of the lake increment, even though it contributes some amount of water continuously. Some of the factors which are responsible for surface area increment and transgression of an immediate surrounding areas are the following:

" Instead of the discharge from the irrigation farm, as to the later study carried out by the Ministry of Water, groundwater is found to be the lading factor for the lake increment. It had already been discovered that sub-surface (subterranean) alimentation amounting to 1.0 to 2.0 m cub./sec play greatest role in the water balance of the lake. In an average, this equates 47 million m³/year.

" On the average, the amount of discharge from the irrigation/Sugar plantation reaches 1.5 to 2.0 m³/sec. This excess water was emptied to the lake Beseka.

" Finger tipped streams, which are calle d rills, are emptying their water into the lake from the southern and western slopes contribute to the water balance of the lake;

Analyses have ascertained that the lake shows a continuing increment of volume as a result of which its transgression engulfs additional areas. According to the Staff Gauge reading, the lake rises 5 cm to 10 cm per month (***Bemetehara Akababiy Silemigegnew Yebeseka Hayik Madeg Yetederege Tinat.' Tahisas 1970 E.C.)***.

9. The Ecological Impact of the Lake's Transgression

The surface area expansion and level rise of Lake Beseka have a great impact on the surrounding ecosystem. Since the late 1960s, this issue has been one of the very sensational ecological incidence in the country. Moreover, persistent surface area increment of the lake has been and is impinging a threat to its neighbouring environment.

Its threat is not confined only to its contiguous environment. The "ecological footprint" of the lake extends over wide and distant areas. Rather irrigated lands and natural features which come in contact with the lake, directly or indirectly, are also under risk. The Tendaho Cotton plantation and other ecosystems along lower Awash river sides are within a potential hazards.

Human beings, the most complex of organisms, are affected by the most subtle variations in water chemistry and supply. The maximum contaminant level (MCL) allowable for drinking water for fluoride varies from 1.4 - 2.4 mg/l (Encyclopaedia of Environmental Science, 1980). But lake Beseka contains great amount of salt chemicals. The analysis made on 30 wells of water samples of Metehara town indicates that, as high as 35mg/l of fluoride is contained in it. This is a good witness to presuppose that the expansion of the lake would result in the underground water pollution.

10. Meliorative Measures

Water pollution is any change in natural waters which may impair their further use, caused by the introduction of organic or inorganic substances, or a change in temperature of the water.

Meliorative and urgent measures are anticipated to save irrigated farms closer to the lake, farms functioning in the lower course of river Awash, and

In summary, earth resources satellite data when properly processed, (and whenever necessary other development activities to be launched in the vicinity., jointly used with other collateral data sources), desired output can be obtained. Every endeavour should be made to find means of combating with omnipresent risk of lake expansion and the consequences. As the result of some occurred loses, not long ago, collaborative studies were carried out by a committee formed constituting specialists from different organizations as a result of damages associated with the lake Beseka's advance. The recommendations and proposals made by the investigators are important and their effort is appreciated.

On the basis of discussions, analyses of the observations and documented facts it is quite necessary to recommend as follows:

(1) Whenever possible excess water from the irrigation channel should be returned into Awash River before it is polluted, instead of draining to lake Beseka. Because, by regulating the water inflow it is possible to reduce the amount of excess water discharged to the lake.

(2) Being conscious of the contributing factors to the lake dynamics, it is necessary to take urgent measures

(3) Provisions should be made in order to implement these recommendations and other proposals which come up with resolving ideas as early as possible. Otherwise the lake may aggravate more the present conditions causing serious damage to the arable land, villages located at the corners of the farm and grazing land.

We all agree with the objective to dry up the source of this long running challenge once and for all. While all the alternative actions considered at present by Ministry of Water have impacts on the lake ecosystem and immediate lake environment, the proposal to lower the lake by draining or pumping to the Awash river has potential impacts on water quality and the riverine ecosystem that may extend downstream from lake Beseka. Any alteration in the chemical structure of the Awash water would result in an adverse effect on different ecosystems, mainly on the Metehara, Tendaho irrigation systems and other development activities and nature along the Awash river. This is because, once channelling begins to river Awash, to maintain lake water balance, it must be constant as longest as sub-surface inflow exists, which is a non-stop.

What is important is to take a long-range view into the future, to plan the trend of source control from hereon, in all its varied applications. Because today's solution shall not be the problem of tomorrow. Therefore, exhaustive feasibility studies should be carried out if there is any chance to extract some minerals from the lake.

11.Conclusion

Timely and reliable monitoring is a prerequisite to effective environmental management. The lack of up-to-date information hinders the process of monitoring and maintaining the ecosystem.

To produce the final output, the raw data acquired from Landsat-MSS, and SPOT-XS systems of different formats and aerial photo were processed. The Remote Sensing and GIS approaches permitted the results of the analysis to be displayed in maps in a limited duration of time. Into a legend of the output map, illustrated in this paper (Figure 2), some important features were identified, classified and presented.

The outputs indicate that simple GIS and remote sensing techniques can be employed to assess very rapidly the expansion of lake areas. Hence, various data sets from different sources have been overlaid to reveal and show the changes very clearly. This sophisticated task has been accomplished successfully by employing GIS Techniques. Unlike the conventional methods, to cite few points, remote sensing is a tool, which provides:

à real/near real time and a multi-temporal data backed by a computer assisted and a high tech analogue, the equipment implemented to study human and natural impacts on the dynamism of land cover,

à cost effective opportunity, for instance, today the majority of resource satellite data are cheaper than almost all aerial photographs, and

à an effective means by which rational methods of land use and ecological equilibrium can be maintained.

The rampant surface area increment of the Lake Beseka has been encroaching on settlement, Addis-Djibouti Railway and the Metehara sugar plantation. The deadliest of all the risks is future salinity if the lake water overfloods irrigated lands.

Regarding the measurement of current surface area of the lake, there is no good agreement with my calculated results and also some of the figures given in some literature. Probably this is because of that we used different methods and different data sources to obtain the results. Almost all earlier studies were based on conventional methods.

Finally, I hope this study can assist concerned prefectural authorities to take the right measures to control this risk and in order to enhance disaster prevention capabilities.

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Irrigation Research Technologies Recommended for sustaining crop production in some irrigated areas of Ethiopia.

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Abstract

Water is very essential for plant growth. It is needed for seeds to germinate, seedlings to emerge, and for plant growth and development. Water p ation of plants, and water provides the transport mechanism for plant nutrients and the products of photosynthesis. When water for plant growth can be controlled by irrigation, average yields under comparable climatic conditions generally are higher than those obtained under rainfed conditions. The difference in yields between irrigated and non-irrigated lands is greatest during seasons that have periods of drought and above normal evaporative demands. Because yields on irrigated lands are higher and more consistent, irrigation plays a major role in stabilizing food and fiber production.

The aim of this paper is to present various experimental outputs on irrigation water management and practices developed for effective, efficient and sustainable agricultural development. All of the outputs were obtained through field experiments except some, which were predicted using climatic data and computer model. Experiments were conducted using Awash River as an irrigation water source in the Awash River basin.

Introduction

In the past, irrigation enabled civilization to establish permanent home sites in semi-arid and arid lands. Today, irrigated agriculture continues to make food and fiber supplies less dependant on fluctuations in climate. Irrigation is one of the oldest known agricultural technologies, but improvements in irrigation methods and practices are still being made. The future will require even greater improvements as competition for limited water supplies continue to increase. Competition for limited water supplies will significantly affect future irrigation development and practices.

In arid areas crops require adequate irrigation to meet, ET needs, but soils must also receive additional water to leach accumulated salts from the root zone. All water obtained from surface streams or subsurface aquifers typically contain dissolved solids. Repeated irrigation leads to accumulation of salts in the root zone as plants extract nearly pure water there by concentrating the salt solution in the soil. Leaching provides a fraction of the applied water more than that which can be retained within the root zone to flush out the concentrated salts that have accumulated.

In areas where natural drainage is very limited, the water table is often controlled by cement or clay tile lines or by plastic drain tubing.

Ethiopia has a total land area of about 124 million hectares. Out of this, about 16.4 million hectares are suitable for the production of annual and perennial crops. Of the estimated arable land, about 8 million hectares is used annually for rain-fed crops. Moreover, the dry land areas of Ethiopia account for more than 66.6 % of the total landmass of the country

The river basins of the country covers about 1,127, 312 km^2 in which a mean of about 112.45 X 10^{9}m^3 volume of water flows from the catchment annually. The potential gross irrigable area of the country is 2,920,130 hectare of land. The groundwater potential in the country is about 2.59 X 10^{9}m^3 (MWR, 1998). This shows that Ethiopia is endowed with water resources, which could be easily tapped and used for irrigation, and the available water resources of the country are sufficient enough to cover the demand for irrigation if the water is properly conserved.

On the other hand, Ethiopia is already suffering from food shortage because of the increasing population and chronic drought occurrence in most parts of the country. Good land and quality sources of irrigation water were fully exploited in most parts of the world. However, Ethiopia has not developed irrigation to the potential it has, i.e. according to the availability of physical resources, land and water only a little more than 3 % of the irrigable land is currently irrigated both in large and medium scale. The development of irrigated areas in the country has also been unevenly spread. Over 70 % of the area developed for irrigation to date are in the Awash River basin. Awash River, which is important for its irrigated agriculture starts in the central plateau and flows to the northeast through the rift valley.

In the semi-arid Awash basin, with the development of new areas, salinity and sodicity became a factor of new concern. Hence, the development and maintenance of successful irrigation practice involves not only the supplying of irrigation water to the land but also the control of land degradation, i.e. salinity, sodicity and rising water table.

One of the research agenda of the research system of Ethiopia is to develop research technologies on crop water requirement of various potential crops for efficient utilization of land and water resources and to develop appropriate technologies for arresting environmental degradation. Based on this, various research recommendations on irrigation, drainage and land reclamation was developed and presented below.

Materials and Methods

1. Crop water use studies
2. Land reclamation
3. Irrigation method

1.Crop water use studies

a) Field experiment

Different irrigation regimes (amount and frequency) were under treatment in randomized complete block (RCBD) design. The experiment was conducted in major irrigated areas of the country under large- scale conditions. This was done for the determination of optimum water requirement of some selected crops in a given period of time.The required amount of water measured with 3-inch partial flume was applied to each plot according to the experimental treatments. Soil moisture was recorded from different soil depth before and after irrigation for uniform water distribution monitoring. Rainfall data was recorded from the near by weather station for the follow up of given irrigation frequency. Agronomic data (plant height, seed weight, seed yield etc.) were recorded. Water use efficiency was calculated using the amount of applied water and crop yield obtained for each of the experiments.

b) Modified pen man method

Potential evapotranspiration was calculated using modified penman equation. The input data used for this analysis was meteorological parameters from the near by weather station of each site. Crop evapotranspiration was determined with the following formula for each crop

ET crop = Kc X ETo

The net and gross irrigation water requirements were also determined for each crop.

2) Land Reclamation:

The land reclamation methods used for the reclamation of salt affected soils and high groundwater areas in the Middle Awash Valley were: a) Subsurface drainage b) Leaching

a) Subsurface drainage:

Subsurface drainage system was installed to reclaim the salt affected soils and intercept the rising groundwater table on pilot drainage scheme. The experimental treatments which were under treatment were different drain spacing (20 m, 40 m, 60 m and 75 m) and to evaluate different filter / envelope materials. Testing of envelope materials were conducted at 40 m drain spacing. The test crop for drain spacing trial was cotton and for that of envelope materials banana. Collector drains were constructed on the lower side of the scheme. Irrigation water was applied for each plots following the recommended irrigation regime of the given test crops. Soil samples were taken for the monitoring of salinity / sodicity hazard. The sample was analyzed for ECe, PH, cation and anions determination in the laboratory. A number of pezometers were installed at different spots for the observation of groundwater table fluctuation. Drain water was collected from each lateral and analyzed for electrical conductivity and pH.

b) Leaching:

Leaching experiments were carried out under 10 m X 10 m basin to leach down the soluble salts. The plots were without crops for the purpose of free leaching practice.

The land was first sub-soiled, leveled and soil bunds, irrigation canals and surface drains were constructed. Graduated sticks were installed on each plot to measure the applied water. The experimental design was randomized complete block (RCB) with 4 replications. A total of 16 plots were under treatment. The experimental treatments were continuous and intermittent ponding of water with 150 mm and 200 mm water applied.

In the continuous ponding water level was replenished as the level reduces every day to maintain the initial level. In the intermittent plots water was applied as the water recedes from the plots. Soil samples were taken from different soil depths of each plot.The samples were analyzed for ECe, pH, cations and anions determination. In-situ measurement of electrical conductivity of the soil was taken with portable conductivity meter.

3)Irrigation method (Furrow evaluation)

The land was prepared and properly leveled. Conventional furrows with 80 cm spacing, 400 m length and different slops were constructed. Wooden pegs were stationed every 25 m of each furrow. Alternate furrows were used for the evaluation. Different stream sizes were maintained for each furrow. The required water was siphoned from the irrigation canal to each alternate system furrows. The required parameters such as advance time, cutback stream, recession period and run-off were recorded.

Results:

Research technologies on agricultural water management studies in some irrigated areas of Ethiopia

Middle Awash:

Middle Awash is found in Semi-arid climatic zone with a long hot summer and a short mild winter. The annual rainfall is 200 to 600 mm. The soils of the research center are 70 % vertisol and 30 % fluvisols. Where as, The soils of the Middle Awash valley as a whole is the reverse.

Cotton:

"The optimum sowing dates for cotton in the Middle Awash region is between 1 to 15 May.

"Optimum irrigation regime for cotton in the Middle Awash has been found to be 75 mm per application every 2-weeks or 125-mm per application every 3-weeks.

"Suitable irrigation system is furrow irrigation with one establishment irrigation of 150 mm.

"Cotton water yield relations were established with 150- mm irrigation water at squaring, flowering and boll formation stages each with two establishing irrigation of 150 mm under Middle Awash condition.

"**Pre-irrigation (150 –mm) practice**

for cotton was justified as an important practice for weed control, germination, and high crop yield.

Kenaf:

¨Usual planting time for kenaf in the Middle Awash region is around Mid-May.

¨Estimated crop water requirement is 839.6 mm seasonally.

¨Irrigation amount of 125 mm every 2 weeks a total of six irrigation gave high yield and water use efficiency.

¨Suitable irrigation system is furrow irrigation

Groundnut:

¨It has been found to grow during the main and off-season in the Middle Awash region but the crop doesn't perform well during the off season.

¨Maximum yields of 69.5 qt/ha were obtained when irrigation was given every 2 weeks at the rate of 125 mm and 75 mm per application.

¨The crop water requirement estimated using modified penman method for a crop planted on may 15 and with a 150-day growing period was 801.55 mm.

¨The optimum irrigation regime of 3-weekly application of 125 mm gave a net seasonal irrigation requirement of 775-mm comprising 150 mm at planting followed by five irrigation up to 120 days.

¨Taking in to consideration the effective seasonal rainfall during the cropping season, the total available water for this crop under the recommended irrigation regime would be 950 mm.

¨Gross irrigation requirement for groundnut in the Middle Awash region will be around 1080 mm assuming irrigation efficiency.

¨Three- irrigation at pre-flowering, peak flowering and pod development gave highest yield.

¨Two irrigation at peak flowering and pod development yielded nearly equal.

¨Recommendations: Three irrigation at;

¨Pre-flowering

¨Peak flowering

¨Pod development

¨Recommendation was 150 m at plant establishment and 125 mm every 21 days up to 105 days.

¨Suitable irrigation system is furrow irrigation

Sesame:

¨Early July and early November planting were optimal for the main and minor seasons respectively.

¨In both seasons, yield depressions were observed that as the sowing dates were delayed beyond July and November.

¨The different irrigation regime did not significantly affect a 3-week frequency and 100- mm application is commonly practiced.

¨With an irrigation regime of 100 mm every 3-weeks the net seasonal irrigation requirement is 450 mm , comprising a 150 mm application at planting followed by 3-irrigation up to 63 days from planting sesame irrigation system.

¨The most suitable irrigation system for sesame is:

¨10 m wide X 140 m long border irrigation

¨Slope 0.1 of along the flow

¨The border irrigation system was considered most suitable for the following reasons.

¨Low labor requirement

¨Simplicity of operation

¨Simplicity of seeding and cultivating by machinery

¨Possibility of mechanical harvesting by using a reaper binder.

¨Recommendation was 100 mm every 21 days until 63 days after sowing

Wheat:

¨Recommendation was given for wheat as 100-mm irrigation water every 10 days.

¨Three irrigation with 125 mm each at Tillering, booting and grain filling period; or Tillering, jointing and grain filling period, or Tillering, anthesis and grain filling period is recommended for wheat crop under Middle Awash condition.

Maize:

¨A sowing date experiment carried out during the main and minor-cropping seasons revealed that the optimum date of planting during the main season was June.

¨November planting was found to be optimum for the cool season.

¨Maximum yield of 56.3 q/ha was obtained when an application of 125 mm every week.

¨Similar yield (51.2 q/ha) was obtained when an application of 125 mm every 2 weeks

¨Looking into water use efficiency and crop yield irrigation water application of 125 mm every 2-weeks.

¨Since maize is a relatively shallow rooted crop, it is particularly sensitive to shortage of moisture and the time of irrigation is critical. The time at which irrigation is given appears more important than the amount of irrigation.

¨It was found that there was no advantage in extending the irrigation beyond 84 days after planting.

¨The estimated crop water requirement for crop planted on first of November is 611.3 mm, which is not greatly different from crops planted in July.

¨With an irrigation application of 75 mm every 2 weeks the net seasonal irrigation requirement is 600 mm, comprising a 150 mm application at planting and 7 to 8 irrigation.

¨The gross irrigation requirement for maize planted in November in the Middle Awash region ranges from 840 to 900 mm.

¨Three irrigation of 150 mm at vegetative, tasseling and grain development is also recommended.

Banana:

¨The water use efficiency and fruit yield were the highest for an irrigation regime of 2-week frequency and 100 mm application.

¨The irrigation requirement under this regime is 1700 mm for a period of 10 months (April to January) resulted in an annual irrigation requirement of 2028 mm. With an effective rainfall of about 430 mm /year, the annual total water use will be around 2450 mm.

¨Based on the modified penman method, the seasonal crop water requirement for banana is 1843 mm / year and, with 75 % irrigation efficiency and an 8 % leaching requirement, the gross irrigation requirement is about 3071.7 mm per annum.

Sweet pepper:

¨Sweet pepper is well adapted for growing in the Middle Awash Valley

¨The highest yields and water use efficiencies were obtained under an irrigation regime of 6 days intervals and 40 mm application.

Crop	Amount (mm)	Frequency	Location
Cotton	75 - 100	2 weeks	Middle Awash
	125 - 150	3 weeks	Middle Awash
	100	2 weeks	Lower Awash (Tendaho)
	125	3 weeks	Gewane
	80	3 weeks	Upper Awash (Merti-Jeju)
	125	3 weeks	Arba-Minch
Groundnut	100	2 weeks	Middle Awash
	150	3 weeks	Middle Awash
Sesame	100	2 weeks	Middle Awash
Maize	100 - 125	1 week	Middle Awash
	150 - 175	2 weeks	Middle Awash
Wheat	100	10 days	Middle Awash
Kenaf	125	2 weeks	Middle Awash
Banana	100	2 weeks	Middle Awash
Onion	50	1 week	Middle Awash
Tomato	90	1 week	Middle Awash
Citrus	50	2 weeks	Middle Awash
Alfalfa	150	2 weeks	Middle Awash

Table 1. Summary of irrigation requirements of some lowland crops

Properties	Dark vertisols	Brown alluvial
Color	Dark Grey when dry, black when wet	Light brown when dry, dark brown when wet
Texture	Silty - clay to clay	Sandy-loam to silty-loam
Consistency	Very sticky when wet Very hard when dry	Moderately sticky when wet, moderately hard when dry
Volume change	Swells when wet, shrinks & develops large crack when dry	Moderate expansion
Basic infiltration rate, mm/hr	5 – 7	10 – 15
Field capacity (%)	46.00	35.70
Permanent wilting point(%)	30.40	19.55
Available soil moisture Dry weight basis %	15.60	16.55
Bulk density, g/ cm^3	1.17	1.33
Pore space, %	50.20	44.2

Source: G.Haider, 1986, review of soil and water management research

Table 2. Physical properties of two main soil types of Middle Awash Region

"With this regime, a total of 810 mm of water is required for one cropping season.

"The estimated crop water requirement of the crop during August to December is 802.78 mm and the gross irrigation requirement assuming 8 % leaching requirement and 75 % irrigation efficiency is 1090 mm.

Onion:

"Onion can be grown successfully during the major and minor cropping seasons.

"In a 3-year experiment conducted at Werer, the crop was found to respond better to irrigation at frequent rater than prolonged intervals.

"Yield of onion tends to decrease as the frequency between irrigation increase and increases with an increase of water duty.

"Maximum fresh bulb yield was recorded for an irrigation regime of one-week frequency and 50 mm application.

"The crop water requirement of onion, as estimated using the modified penman method, is 516.87 mm for crops planted in October and growing for 120 days.

"With irrigation regime of 50 mm applied weekly the net irrigation requirement ranges between 850 and 900-mm and the gross irrigation requirement ranges between 1100 and 1200 mm.

Alfalfa:

"Alfalfa is well adapted as a lowland pasture and can be grown under irrigation.

"Alfalfa was found to respond best to shorter irrigation intervals and at higher rates of water application.

"The maximum yield was obtained with an irrigation regime of one-week and 100 mm application.

"In terms of water use efficiency, both one week and 50 mm application and 2-week frequency and 100 mm application are equally important.

"From the management point of view, 2-week frequency and 100 mm application is optimum regime.

"The net irrigation requirement under this regime is 6300 mm, 26 mm per month

"Using modified penman for a growing period of 365 days the crop requirement is 2273.65 mm.

"The net irrigation requirement for an irrigation regime of 2-weeks and 100 mm application is 2700 mm.

Gode:

Groundnut:

"Maximum yield was obtained under an irrigation interval of 6 days and 150 mm per application

"Recommendation was 100 mm every 6 days

Sesame:

"Shorter irrigation intervals (7-14 days) were better than longer ones

"Heavier water applications (10 –15 cm) were better than application of 5 cm.

"Maximum yield of 13.6 q/ha was obtained for an irrigation regime of 2 weeks and 15 cm application.

"Recommendation was 100 – 150 mm every 14 days

Tendaho:

Cotton:

"Yield declined progressively as irrigation frequency was increased from 2 to 4 weeks and increased with an increase of water application.

"Yield depression was also observed when irrigation was prolonged beyond 120 days.

"Weekly irrigation application gave the highest yields. This is because of high evapotranspiration.

"Recommendation was 100 to 125 mm of irrigation water every week.

Arba Minch:

Cotton:

"Recommendation 125 mm every three weeks.

Gewane:

Cotton:

"Recommendation was 175 mm irrigation water every 3-week intervals.

Drainage and Reclamation

"Intermittent leaching method with single application of 200-mm water depth every recession period could be applied for cotton crop as a free leaching practice for reclaiming salt-affected soil with sub-surface drainage pipe under Middle Awash condition.

"Sub-surface drainage system is effective in controlling ground water table depth and soil salinity level under Middle Awash condition with the following components:

"Corrugated plastic pipes (PVC) with 60 and 80 mm nominal diameter.

"Red-ash as envelope material

"Drain spacing of 40 to 60 m

"Drain depth of 1.7 to 2.0 m

"In the Middle Awash Valley, where

Characteristics	Location		
	Werer center	Melka Sedi	Amibara
Optimum initial stream flow rate (liters/sec.)	3.44	2.34	3.50
Cut-back stream flow rate (liters/sec)	0.72	1.72	1.42
Optimum furrow length(m)	205.00	190.00	210.00
Application efficiency %	97.00	78.00	62.00

Table: Optimum stream flow rates and furrow lengths

evapotranspiration is greatly exceeding precipitation, it is advisable to keep the land wet under continuos cropping to avoid movement of salt to the surface from shallow ground water in course of alternate wetting and drying.

Future Research Focus/ direction

1.Inventorize, characterize, test and improve indigenous knowledge / traditional practices of agricultural water management.

2.Research attention on small scale irrigation practices (Irrigation regimes (amount, frequency) irrigation methods etc)

3.Supplementary irrigation using rainwater harvesting techniques (spate irrigation)

4.Studies on ground water irrigation (surface, pressurized)

5.Evaluation of more efficient irrigation methods (sprinkler, drip)

6.Development of water saving technologies.

7.Develop and strengthen adaptive research using already developed technologies

8.Research on different drainage techniques (surface, subsurface, mole etc.) for the establishment of design criteria.

9.Research on problem soils (water logged, saline /sodic soils)

10.Development of watershed management technologies

11.Development of appropriate and environmentally friendly technologies for sustained use of wet lands (marshy/ swampy)

Irrigation Scheduling in the Gandak Command Area

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Abstract

When to irrigate and how much water to apply have been the important equations since the quest for better water management started in the early part of the twentieth century. The necessity to answer these questions more precisely has only grown with time. The determination of date and depth of irrigation is mainly related to soil-moisture content, evapotranspiration, the relationship between moisture stress, and the crop yield, crop and climatic conditions. The evapotranspiration alone, which gives consumptive use of plant is a function of meteorological factors, nature of crop and its canopy, crop growth stage and the drought resistance for each stage. Although there is increase in the basic understanding of the soil-water-plant-irrigation scheduling, there are a number of constraints that come in way of their adoption at field level, e.g. unsuitable water distribution schedule, poor on farm water management, lack of land shaping and land grading, absence of water users' associations and non-participation of the beneficiaries in the decision making in respect of water distribution schedule. These aspects have been discussed in detail with respect to Shampur minor of Bhagwanpur distributary of Gandak Project in Bihar, India. A model irrigation scheduling has also been proposed for rainy, winter and summer seasons for the area under study.

Introduction

Water is the most essential natural resource for life next to air and is likely to become a critical scarce resource in the coming decades. It has been estimated that India possesses only 1 percent of the total average annual runoff in the rivers of the world. The ultimate irrigation potential of the country has been estimated by Central Water Commission of India as 113 mha against which a potential of 80.2 mha has already been created by the end of 1989 - 90 [1].

To most of the irrigation managers, irrigation scheduling means *warabandi* i.e. a system of water distribution by means of which equitable distribution of water as per share of each farmer is ensured. This, although important, is a very small part in the sphere of irrigation scheduling. *Warbandi* does help to a great extent in ensuring deliveries of water as per share of cultivators at fixed intervals of time, but it does not ensure the delivery of water in the required quantity and at the required time [2]. Application of water at fixed intervals of time irrespective of the consumptive use of plants may result either in over-irrigation causing reduced aeration of plant roots and/ or leaching of nutrients or causing water stress due to under-irrigation. In both the cases, it will cause reduction in crop yield. The study of Janjokhar minor in Salawa command area of Ganga Canal in Western Uttar Pradesh, India has shown that by and large, the farmer gets the same depth of water application during all waterings because of *osrabandi* schedule irrespective of the crop growth stage [3].

An irrigation water need of 5 mm/ day does not mean that this 5 mm has to be supplied by irrigation everyday. In theory, water could be given daily. But, as this would be very time and labour consuming, it is preferable to have a longer irrigation interval, which in turn, will depend upon the effective root depth of the crop and type of soil. It is, for example, possible to supply 15 mm every 3 days or 25 mm every 5 days. The irrigation water will then be stored in the root zone and gradually be used by the plants at the rate of 5 mm/day. The irrigation interval has to be chosen in such a way that the crop will not suffer from water shortage.

It has been established by research workers that some plant (e.g. sorghum) increases their water utilization efficiency while others (e.g. maize) decrease it under stress. Yield per unit area may reduce for both types of plants growing under moisture stress conditions with a greater relative reduction for those that decrease their water utilization efficiency under stress. Yield per unit of water, however, is not necessarily reduced and in most crops, production per unit of water increases under moderate stress conditions, provided the stresses do not occur during critical growth stage. In some cases, stress condition may be timed to be beneficial because harvested yield of some crops like cotton and sugarbeet, increases when stresses occur at a particular period [4].

In the present paper, irrigation scheduling for a few representative crops in the command of Shampur minor of Bhagwanpur Distributary under Vaishali Branch Canal of Tirhut main canal system of the Bihar portion of Gandak project, which is an International Major Irrigation and Power Project involving India and Nepal, has been done. The location map of Gandak Project has been shown in Fig-1. A part from this, some important constraints related with irrigation scheduling in the command of run-of-the-river schemes (which is the case in North India) have also been described. Based in this, some useful conclusions have been drawn.

Materials and Methods

A qualitative approach of irrigation scheduling is based on human sensing and identifying the proper time for irrigation by co-relating various soil, crop and climatic performance parameters to the crop demand. Feeling the soil dryness, watching the plant colour as a measure of stress, counting days since last irrigation etc. are among the most common qualitative methods of human sensing and identification of irrigation needs. Although in some individual

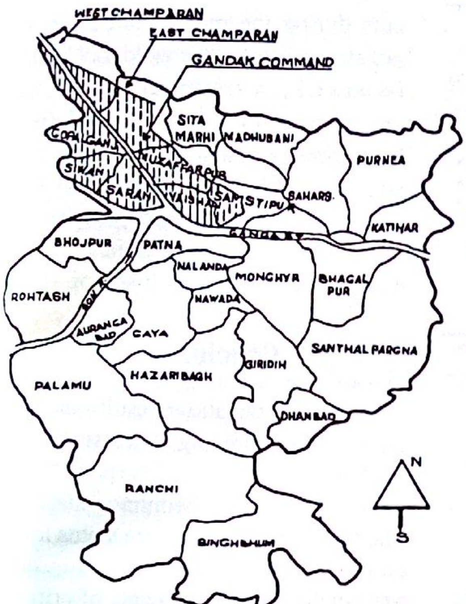

Fig. Locatin of Gandak Command

cases, such a procedure may be efficient and successfully applied, but in general, it may lead to improper decisions such as irrigation too early or too late and with depths of application that are too low or too high. However, in the present treatment, the effective root depth with respect to age of crop, effective soil depth, available moisture condition, crop evapotranspiration and management allowable depletion for different crops for un-stressed condition as per Food and Agricultural Organisation, Irrigation and Drainage paper number 24 [5] have been considered for estimation of irrigation scheduling for crops under study, i.e. maize (Kharif), lowland rice (Kharif), Wheat (Rabi) and green gram (Hot Weather).

The irrigation internal for non-ponded crops has been calculated with the help of the following equation [5]:

$$i = (p.S_a.D)/ET_c \quad (1)$$

Where:

p = management allowable deficit

S_a = Total available soil water (mm/m)

D = Root depth (m)

ET_o = Crop evapotranspiration (mm/day)

i = Irrigation interval (days)

For lowland rice the crop water requirement is equal to crop evapotranspiration plus deep percolation losses. For example, say, it is required to maintain 100 mm constant depth of water in the field. If deep percolation loss, on an average, is 5 mm/day and ET_c for low land rice taken as 5 mm/day then the irrigation internal for this crop will be 100/(5+5) = 10 days.

The study area comes under the command of Shampur minor ex. RD.31.25 (9.53 Km) on left side of Bhagwappur distributary which takes off from Vaishali Branch Canal of Tirhut Main Canal system of Gandak project. The area is situated at altitude 55.78 m longitude 83° 15' E and latitude 26° 32. 4' N. The texture of the soil is sandy-loam, therefore, available soil water was assumed to be equal to 180 mm/m [5]. The reference evapotranspiration times the crop coefficient gives the crop-evapotranspiration which were obtained after getting crop coefficients for the crops under study by developing crop-coefficient (k_c) curves for these crops as per [4] and [5].

Special needs of water for crops should be determined by actual observation for a specific situation. However, for the present study, the special needs have assumed as given in Table 1. For the present treatment, it has been assumed that the pre-sowing irrigation for non-ponded crops (if required) has already been given in the field.

Sl. No.	Operation	Type of soil	Quantity of water (mm)
1.	Land preparation	Light soil medium soil heavy soil	50 75 90
2.	Transplantation Rice Rice Other crops Other crops	Light soil heavy soil light soil heavy soil	300 200 100 75

Table 1. Special Needs of Water for Crops [6]

Sl. No.	Crop	Season	Date of sowing	Growth Stages (days) I	II	III	IV	Duration (days)
1.	Paddy*	Kharif	1 JUN	-	-	-	-	135
2.	Maize	Kharif	16 JUN	20	30	40	30	120
3.	Wheat	Rabi	25 NOV	15	25	50	30	120
4.	Green gram	Hot Weather	15 MAR	15	20	25	20	80

* For paddy growth stages are 1st and 2nd months, mid-season and last four weeks [5].

Table 2. Different Growth Stages of Crops Under Study.

The sowing dates, growth stages and durations of crops under study based on interview of the farmers of the project area have been given in Table 2. The depth of rooting with respect to age of the crop and management allowable deficit factor (p) has been gives in Table 3. These values have been increased by 30% when ET_c was less than 3 mm/day and were decreased by 30% when ET_c values were more than 8 mm/day [5].

Based on these data and the methodology described above, Irrigation Scheduling was done for the representative ponded (low land rice) and non-ponded crops of different seasons i.e. Kharif, Rabi and Hot Weather.

Results and Discussion

The results of irrigation scheduling for maize and paddy, wheat and green gram have been given in Table 4, 5 and 6 respectively. From Table 4, it is clear that the irrigation interval of maize varies from 9 days in June to 23 days in October. However, on an average, the irrigation internal may be kept as 14 days for maize for optimal yield. Similarly for paddy, it is seen that the irrigation interval varies from 2 days in June to 8 days in July and 5 days in September. The minimum irrigation interval of 2 days in June may be attributed to the special needs of land preparation and transplantation. However, on an average, irrigation interval for paddy may be adopted as 4 to 5 days. It is remarkable to note that no irrigation has been proposed during October. It is simply due to the reason that only a few days are taken by paddy in October and also it is in its maturity stage.

From Table 5, it is seen that the irrigation interval for wheat varies from 4 days in November to 21 days in March with a maximum of 27 days in December. However, on an average, irrigation interval for wheat may be kept as 19 days for the area under study. Similarly from

Sl. No.	Crop	Duration (days)	Management Allowable deficit	Rooting Depth in cm at different stages (days) 15	30	45	60	75
1.	Paddy	135	-	10	20	25	35	*
2.	Maize	120	0.50	20	50	75	100	*
3.	Wheat	120	0.55	20	40	60	90	*
4.	Green Gram	80	0.10	20	50	60	*	*

* Indicates the same depth of root for other crop period

Table 3. Effective Depth of Roo!s Under Unrestricted Soil Conditions of Crops Under Study [7]

Sl. No.	Crop	Date of sowing	p factor	Scheduling parameters	June	July	Aug.	Sept.	Oct.
				Etc(mm/day)	7.60	6.87	6.41	5.86	5.3
1.	Paddy	1 June		D (m)	0.15	0.25	•0.35	0.35	0.35
				I S* (days)2	8	4	5	-	
				ET_c(mm/day)	1.29	3.50	6.70	5.67	3.95
2.	Maize	16 June	0.50	D (m) 0.10	0.50	0.93	1.00	1.00	
				I.S. (days) 9	13	13	16	23	

Table 4. Irrigation Scheduling for Paddy and Maize(Kharif Season).

Sl. No.	Crop	Date of sowing	p factor	Scheduling parameters	Nov.	Dec.	Jan.	Feb.	Mar.
				ET_c(mm/day)	1.25	1.37	3.14	4.67	4.15
1	Wheat	25 Nov.	0.55	D (m) 0.04	0.29	0.74	0.90	0.90	
				I.S. (days) 4	27	23	19	21	

Table 5. Irrigation Scheduling for Wheat (Rabi Season).

Sl. No.	Crop	Date of sowing	p factor	Scheduling parameters	March	April	May	June
				ET_c(mm/day)	1.60	6.36	7.04	4.39
1	Green gram	15 March	0.40	D (m) 0.10	0.40	0.60	0.60	
				I.S.*(days)4	5	6	10	

* Irrigation scheduling

Table 6. Irrigation Scheduling For Green Gram (Hot Weather Season).

Table 6, for green gram, the irrigation interval varies from 4 days in March to 10 days in June. However, on an average, irrigation interval of 7 days may be adopted for this crop for good yield.

The above method of estimation of irrigation scheduling is based on the average irrigation water need of crop which is the average crop water need minus the average effective rainfall. This method may be used while designing and implementing an irrigation system with a rotational water supply i.e. each field will receive a certain amount of water on dates which are already fixed in advance. It takes into account the average rainfall only and thus does not take into account the actual rainfall. This may result into over-irrigation or under-irrigation. However, in demand based irrigation system, farmers can take water whenever necessary. In this case, it is possible to take the actual rainfall into consideration. Although in such cases, the rainfall has to be measured on a daily basis. Therefore, in supply based irrigation system e.g. irrigation projects of North India, the scheduled date of irrigation may be shifted for a few days based on the quantum of rainfall for maximum utilization of irrigation water.

The above treatment has been discussed assuming no shortage of water. But, the gravity of the problem increases where assured and reliable water supply is not available. In North India, most of the canal systems are run-of-the-river schemes and canal water is available to the farmers according to his turn on a roster basis and a farmer gets the water during the period allotted to him. If his luck favours, he may get three or four waterings during rabi season; otherwise he may have to be contented with still lesser frequency of watering. Obviously, this availability of water is hardly related to crop growth stages. But the fact is that, out of four growth stages, namely, initial stage, crop development stage, mid-season stage and late season stage, the mid-season stage is the most sensitive stage to water shortages. This is mainly because it is the period of the highest crop water needs. If the water shortage occurs during the mid season stage, the negative effect on the yield will be pronounced. In an irrigation project, if only one crop is grown, but not all fields have been planted at the same time (staggered planting) and water is in short supply, it is advisable to give priority to irrigate those fields in which the crop has reached the mid-season stage.

Conclusions

Based on the above results and discussion the following conclusions may be drawn:

i. Irrigation scheduling may be planned from soil moisture status level consideration, which may be adjusted marginally for requirements of critical stages.

ii. In some cases, stress condition may be timed to be beneficial because the harvested yield of some crops like cotton and sugar beet, increase when water stresses occur at a particular period.

iii. For the project area under study the irrigation interval for low land rice (Kharif), maize (Kharif), wheat (Rabi) and green gram(Hot Weather) may be kept at 5, 14, 19 and 7 days respectively for good yield.

iv. In supply based irrigation system scheduled date of irrigation may be shifted for a few days based on the quantum of rainfall for maximum utilization of water.

v. Staggering of crops may be encouraged so as to meet the peak demand of those crops which require more water during their mid-season stage i.e. flowering and yield formation stage.

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Determination of Eutrophication Factors in Boye Pond. Jimma, Southwest Ethiopia, Feb. 1997.

Mitiku wacho, Worku Legesse

Introduction

Boye pond which is located at about 4 Km to the east of Jimma town, was come to bieng in 1967 by Jimma city Council aimed to conserve Hippopotamus and recreation purpose.

Such type of pond, which is constructed across a valley to form a reservoir where water is stored, is known as hill-type pond. Such type of pond can provide water for crop irrigation, livestock and recreation, as well as yield substantial quantities of fish(Huner, 1995).

The pond receives water from two streams; Kitto and Awetu. They enter the pond after converging at about 2Km above the pond. Awetu, passing through Jimma town receives all types of Municipal wastes, and discharged to the pond with extensive amount of pollutants. Due to this fact, at present Boye pond is in the state of progressive Eutrophication. There is extensive growth of aquatic vegetation, which seriously impedes fishing, boating and swimming. There are emergent plants rooted at the bottom and growing above the surface of water along the shoreline. As a result the pond has lost the objective for which it was designed. Its recreation value is unthinkable as the situation is changed. It emits bad odor due to anaerobic decomposition, as a result of extensive waste laod. This can result in the rise of Biological Oxygen Demand and depletion of oxygen in the water which leads to the death of aquatic animals(Lauiran, 1995.)

Eutrophication factors, phosphate and Nitrate are present in sewage from cities, from feedlots, from artificial fertilizer put in the crop, from septic tank and from natural sources. In the city sewage much of the nitrate and phosphates come from human wastes. Adding of these nutrients through these processes to fresh water may encourage such an explosion in the algal population that a "bloom" results. while algal bloom presence increase productivity of the ecosystem, they are undesirable for several reasons. The respiratory needs of algae may so deplete the oxygen content (DO) of the water during the night that fish suffocate. Further more the decay of aquatic weed may cause such unpleasant tastes and odor to the water as to degrade its attractiveness. This becomes a wide spread problem in the most countries with large populations and intensive agriculture(AMBIO,1992).

Where both nitrogen and phosphorus are plentiful, algal bloom occurs which may produce a variety of nuisance conditions. Phosphorus appears to be the most practical nutrient to control. (Salvato, 1992)

Materials and methods.

The pond was divided into three stations to have representative samples for analysis. The samples were collected for three days using wagtech lea liter a crylic water bottle (catalogue number 7500-B20) and clean glass stoppered glass bottle were used to transport the samples to the laboratory by storing in an icebox with in two hours.

The collected samples were analyzed by using standard laboratory methods: Stannous chloride for orthophosphate, direct nesslerization for Ammonia, Phenol disulfonic acid method for Nitrate Nitrogen, open reflux titrimetric for COD, the Acid modification now Winkler method for DO and conventional titration method for BOD, pH meter (glass electrode) for pH and temperature, and Turbidometer model 46500 for turbidity. Finally the results were analyzed and tabulated.

Results

1. Nutrients

Phosphate had similar concentration throughout the sites. It was 0.058,0.081 and 0.068 mg/ L at site 1, 2 and 3 respectively, and as phosphorus the mean concentration was 0.202 mg/L (Table 1). Nitrate concentration was found to decrease down the pond, which was 0.3 mg/L, 0.195 and 0.075 mg/ L at site 1, site 2 and site 3 respectively (able 1). Similarly the nutrient contribution of the two rivers (Kito and Awetu) was determined and Awetu was found to contribute about 2.6 times greater concentration of phosphorus than that of Kito (table1).

2. Selected physical & chemical parameter

The selected parameters were generally found to fluctuate down the pond and are shown in table 2 and table 3.

S.No	Parameter*	Site1	Site2	Site3	Awetu	Kito
1	PO_4^{-3} mg/1	0.058	0.081	0.068	0.168	0.064
2	as P "	0.189	0.199	0.222	0.548	0.21
3	NO_3 -	0.3	0.195	0.07	0.642	0.3
4	NO_3N "	0.68	0.044	0.046	0	0.0585

*All values given are the mean of three measurement

Table 1 The nutrient concentration of Boye pond at different sites with relative contribution from Awetu and Kito.

S.No	Parameter*	Site 1	Site 2	Site 3
1	BOD(in mg/1)	10.4	6.4	6.0
2	COD "	126.7	51.5	31.7
3	DO "	5.2	3.9	0
4	NH_3N	1.16	0.303	0.286

*The values given are the mean of three measurements

S.No	Parameter*	Site 1	Site 2	Site 3
1	Temperature (°C	24.5	24.0	20.3
2	PH	6.45	8.77	6.03
3	Turgidity (NTU)	159	58	13

*All Value given are the mean of three measurements.

Table 2 The BOD, COD, NH^3 DO level at different sites of the pond

Discussion

The most characteristics sign that a reservoir is undergoing Eutrophication is the formation of green scum consisting of millions of microscopic algal cells on the surface of water and growth of aquatic weeds along the shore line (Charles, 1980). Boye reservoir has showed these typical characteristics, Eutrophication, which is associated with elevated concentration of nitrogen and pl osphorus. The critical value for phosphorus has been established as some where near 0.005 mean concentration of phosphorus in the Boye pond was 0.2 mg/L, which is about 4 times the critical value. It was also indicated that any reservoir or lake having 0.01mg/l phosphorus and 0.3 mg/L Nitrogen can expect to have major algal bloom (Salvato, 1992).

The relative contribution of nutrients from the two streams (Kito and Awetu) has showed reasonable results as expected. Phosphorus contribution of Awetu stream (Table 1) is about 2.6 greater than that of Kito. This is because of the fact that Awetu receive effluents and liquid wastes indiscriminately discharged from Jimma town, and effluent is known to contain large concentrations of nitrate and phosphate.

The BOD and COD were found to decrease down the pond. This may indicate that some stabilization was achieved as the pond has sluggish flow. The pH value has increased at the center (site 2) that indicates the high algal "Bloom" which cause alkaline condition during metabolism (Sawer, 1994).DO level of Boye pondis generally at concentration that endangers aquatic life (table 2), for it was indicated that the lower DO of water body decrease biologic diversity (Anne, 1990). The DO level was found to decrease down the pond even though BOD was decreased. Starting near site 2 the pond was covered by aquatic weeds and oil layer which might have hindered surface absorption of might have hindered surface absorption of oxygen while the existing DO was depleted due to respiration and stabilization of organic wastes under the layers. As a result DO concentration at site 3 down stream to the covered surface was found to be zero up to the surface level. This has created obnoxious odor due to an-aerobic condition in the pond. It was created unpleasant odor to its surrounding.

Generally due to the above mentioned reasons the recreational value of the reservoir has deteriorated hippopotamus were migrated to mini Gibe river, therefore it has lost the objective for which it was designed. In addition the surrounding people were complaining that vast land area covered by eutrophied pond with out any use. It was also suggested that this vast land area could have been used for different irrigation purposes if the water was permitted to go on its natural stream or if it were not impounded.

Conclusion and Recommendation

It is evident that the general ecosystem of Boye pond is perturbed due to human interference for amenity purpose. However, the purpose of impounding the river is not considered the environmental impacts. In addition no follow up was taken to maintain ecological balance and biological diversity. These have resulted in migration of hippopotamus, abnixicous odor and nuisance environment, a good breeding site for mosquito, and reduction of fishery products. At present the pond has generally lost its designed purposes and needs extensive remedial measures to sustain its ecological integrity. Therefore, the release of the impounded water and control of effluent entering the pond that enhanced the level of nutrients need to be considered as alternatives to restore the normal river flow and save the natural ecosystem of the dying pond.

With this in view the following recommendations are forwarded for consideration.

1.Further research is required in the area of

-Biological aspect of the reservoir

-Detail environmental impact assessment

2.There should be a wastewater treatment plant for effluent entering into the pond to reduce the level of eutroplication and pollution status.

3.The impoundment should be released so as to maintain self purification, aeration and restoration of the natural river Ecosystem.

4. Environmental protection agency should be empowered for technological based effluent regulation.

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Enzymatic Characterization of Activated Sludge From Wastewater Treatment Plant With Foaming Incident

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Abstract

Activated sludge samples collected from a treatment plant, with foaming experience in the month of July, was characterized enzymatically. Hexokinase, Glyceraldehyde-3-phosphate dehydrogenase and Adenylate kinase activity assays were conducted before, during and after the foaming episode. The spectrum of enzyme activities demonstrated change in the biochemical activity of the activated sludge, with peaks in the foaming month. Significant difference in enzyme activities was found between the foaming and nonfoaming months. The potential use of these enzymes in foam prevention and control is implied. Foaming incident was associated with increase in phosphate and lipid contents in the influent.

Keywords and phrases: Activated sludge, Adenylate kinase, enzyme activities, foaming, Glyceraldehyde-3-phosphate dehydrogenase, Hexokinase, wastewater.

Introduction

Biological treatment of sewage waste takes many forms. One of the most common of these is the activated sludge process. It is a two-stage operation involving an initial aeration followed by sedimentation (Painter, 1978; Soddell and Seviour, 1990). The incoming waste is a dilute solution of organic compounds containing a wide range of microbes, and showing variations in both flow rate and nutrient content. The aeration stage occurs in a large basin that is extensively aerated, allowing a large number of filamentous and nonfilamentous bacteria, fungi, protozoa, rotifers and nematodes to take part in a complex ecosystem. An essential requirement for successful operation of the activated sludge process is the formation of a suitable floc of microorganisms in the aeration tank so that separation of solids can subsequently occur in the sedimentation tank, producing a clear supernatant fluid. Some of these settled sludge solids are then recycled into the primary aeration tank, allowing an increased level of microbial activity to be maintained in it.

Although the biological treatment of wastewater by the use of the activated sludge process has many advantages concerning its flexibility and efficiency, its operation is plagued by two problems both of which have an association with the presence of filamentous microbes. One of these problems is poor settlement due to bulking and the other is the formation of foams. Foaming involves filamentous bacteria, and manifests itself as a persistent viscous brown foam or scum on the surface of the mixed liquor in the aeration vessel and sometimes on the secondary clarifier (Soddell and Seviour, 1990). The presence of foam can affect plant operation in several ways: it can pass into and persist in the final settlement tanks resulting in unacceptably high concentrations of suspended matter in the final effluent; it can reach a stage where the upper most part of the foam dies and in decomposing, creates an odorous nuisance, and in extreme cases, it can spill out of the aeration tank into walk-ways creating a nuisance to site workers (Godder and Forster, 1978).

Foaming can be prevented or its severity can be minimized if there are rapid and reliable methods to measure microbial activity in the activated sludge. The microorganisms in the activated sludge convert complex particulate and dissolved matter into low-molecular weight compounds by extracellular hydrolytic enzymes. The low-molecular weight compounds are subsequently taken up by the cells and used as energy and carbon source in cell metabolism. Hence, enzyme systems likely to reflect microbial activity would be either enzymes participating in the extracellular hydrolysis or key enzymes in the cellular oxidative metabolism (Nybroe *et al.* 1992). It has been suggested that enzyme assays might be used to characterize microbial activity in activated sludge (Weddle and Jenkins, 1971; Teuber and Brodisch, 1977; Richards *et al.*, 1984). Nybroe *et al.* determined dehydrogenase and esterase activities in the wastewater input to the pilot scale treatment plant, during a 12 day period, variations in gross enzyme activities correspond to variations in volatile suspended solids and in number of culturable bacteria. This suggests that enzyme activities reflect microbial activities in wastewater.

Foaming is a common phenomenon at the Leutschach wastewater treatment plant (Styria, Austria) in the month of July. Therefore investigation on this treatment plant was carried out to follow the activity of activated sludge before, during and after foaming. The aim of this study was to characterize activated sludge from the Leutschach wastewater treatment plant with Hexokinase, Glyceraldehyde-3-phosphate dehydrogenase and Adenylate kinase assays.

Materials and methods

Description of the study site and sampling

The Leutschach wastewater treatment plant is located in Styria, Austria about 80 km south of Graz. It mainly receives domestic wastewater from the village Leutschach. Wastewater also comes from Wine Brewers locally called the "Buschenschanks". The treatment plant is an activated sludge system having two parallel aeration basins (B-I and B-II), clarifiers and sludge collection system. Sludge is recycled from one of the clarifiers and excess sludge is collected with sludge collection system for ultimate disposal. The effluent from the clarifier is released into a nearby stream. Some operational parameters of the wastewater treatment plant were obtained from Joanneum Research (Appendix A). Wastewater samples for enzyme assays were collected from the aeration basins of the treatment plant between April and October 1997. and characterised with Hexokinase, Glyceraldehyde-3-phosphate dehydrogenase and Adenylate kinase assays.

Enzyme assays

The assay of these enzymes was based on the measurement of the change of absorbance of the coenzymes NADP and NADH at 340 nm in the presence of substrates (Bergmeyer, 1974). Coupled assays were employed for all enzymes. The crude cell-free extract was added to other components of the assay mixture, and change in absorbance at 340 nm was measured with a UVKON 940 spectrophotometer. Molar extinction coefficient (e) of 6270 for NADH and NADP was used for calculation of enzyme activity (Passonneau and Lowry, 1993).

All enzyme assays were performed at room temperature using quartz cuvettes of 1-cm path length in a UVIKON 940 spectrophotometer (Kontron Instruments AG; Zurich, Switzerland). To harvest cells, the samples were centrifuged at 5,000 revolutions per minute (rpm) for 20 minutes in Sorvall RC-5B Refrigerated Centrifuge (Du Pont Instruments; Hamburg, Germany). The cell pellet was washed twice with 0.1 M Triethanolamine buffer (pH 7.6) and suspended in the same buffer. Then the cell pellet was disrupted by sonication for ten minutes using SONOPULS HD sonicator (MANDELINE electronics; Berlin, Germany). Cell debris was removed by centrifugation of the homogenised suspension at 20,000 rpm for 25 minutes. The supernatant was used for enzyme assay immediately.

1. Hexokinase (HK), [ATP: D-hexose,6-phosphotransferase, EC 2.7.1.1.] assay.

Hexokinase activity was determined by coupling the formation of glucose-6-phosphate to the reduction of NADP in the presence of glucose and an auxiliary enzyme, glucose-6-phosphate dehydrogenase (G6PDH).Cuvettes contained: 1 ml of 0.1 M Triethanolamine buffer, pH 7,6, 1 ml of glucose (100 mg/ml), 200 µl $MgCl_2$ (0.1 M), 200µl NADP (10 mg/ml), 100 µl ATP (10 mg/ml), 10µl G6PDH (1mg/ml). The components of the assay mixture were mixed and the cuvettes were placed in the cuvette holder of the photometer and 20µl crude cell-free extract was added. Reference cuvettes contained all components of the assay mixture except glucose.

2. Glyceraldehyde-3-phosphate-dehydrogenase (GAPDH) [D-Glyceraldehyde-3-phosphate: NAD Oxidoreductase (phosphorylating), EC 1.2.1.12.] assay.

Glyceraldehyde-3-phosphate-dehydrogenase was assayed by coupling ADP formation to oxidation of NADH in the presence of a coupling enzyme, phosphoglycerate kinase (PGK) and glycerate-3-phosphate. Cuvettes contained: 2.5 ml of 0.1 M Triethanolamine buffer, pH 7.6, 200 µl Glycerate-3-phosphate (50 mg/ml), 100 µl ATP (20 mg/ml), 100µl EDTA (10 mg/ml), 50 µl $MgSO_4$ (0.1 M), 50µl NADH (10 mg/ml) and 10µl PGK (10 mg/ml). The components of the assay mixture were mixed and the cuvettes were placed in the cuvette holder of the photometer and 20µl crude cell-free extract was added. Reference cuvettes contained all components of the assay mixture except glycerate-3-phosphate.

3. Adenylat kinase (AK) [ATP: AMP phosphotransferase, EC 2.7.4.3] assay.

Adenylat kinase was assayed on the basis of measuring progress of the reaction in the direction of ATP utilisation, using pyruvate kinase (PK) with excess phosphoenol pyruvate (PEP) together with lactate dehydrogenase (LDH) and NADH. Cuvettes contained: 2 ml of 0.1 M Triethanolamine buffer, pH 7.6, 200 µl A-5-MP (10 mg/ml), 200 µl ATP (10 mg/ml), 100µl PEP (5mg/ml), 100 µl $MgSO_4$ (32 mM), 100µl KCl (4 M), 50µl NADH (10 mg/ml), 10µl PK (10 mg/ml) and 20µl LDH (5 mg/ml). The components of the assay mixture were mixed and the cuvettes were placed in the cuvette holder of the photometer and 20µl crude cell-free extract was added. Reference cuvettes contained all components of the assay mixture except phosphoenol pyruvate.

Protein determination

The amount of protein in the crude cell extract was determined according to the procedures of Lowry *et al.* (1951). All substrates, enzymes, coenzymes and nucleotides were obtained from Boehringer Mannheim GmbH, Vienna.

Results

To trace the activities of the activated sludge during foaming and non-foaming periods, wastewater samples were collected between April and October 1997 and analyzed with hexokinase, adenylate kinase and glycerinaldehyde-3-phosphate dehydrogenase activity assays. As shown in figures 1- 3 similar activity profiles were obtained for the three enzymes through out the study period. In general no considerable increase or decrease in enzyme activities were observed between April and the middle of June. Enzyme activities started increasing in the second week of June and reached their maximum in the middle of July followed by a gradual decline. Enzyme activities recorded in April, May and early June were restored in the second week of August. The activities remained nearly constant in the last two weeks of August, during the entire weeks of September and October. Peak enzyme activities were recorded during the month of foaming i.e. July, with apparently no variation in activities one month before and one month after the peak foaming episode. The only exception to the general pattern is the hexokinase and adenylate kinase activities measured on 23 June, which were exceptionally high.

One way analysis of variance (ANNOVA) was carried out to test if there is significant difference in enzyme activities of the activated sludge between the foaming month (July) and non-foaming months, one before one after the foaming episode. Significant differences in enzyme activities were found between the foaming and non-foaming months (May and July).

Discussion

The spectrum of hexokinase, adenylate kinase and glyceraldehyde-3-phosphate-dehydrogenase activities clearly showed a sign of change in the physiological activities of the activated sludge organisms. It was possible to demonstrate differences in activities of the activated sludge between the times of foaming and during normal operation of the system with enzyme assays from the cell free extract of the activated sludge. Significantly higher enzyme activities were recorded during the foaming month than the non-foaming months. This is an indication of change in the physiological property of the micro-organisms or changes in the species composition of the microbial population from one dominated by floc forming organisms to one dominated by filamentous organisms that are responsible for foam formation.

Activated sludge foaming is most commonly connected with an enormous increase in biomass of nocardioform actinomycete bacteria (Lemmer, 1986). It was originally thought foaming is caused mainly by *Nocardia amarae*. However, more recent surveys have revealed the presence of a much wider range of filaments in foams, including other nocardioforms, *Microthrix parvicella* and several Eikelboom morphological types (Godder and Forster, 1987; Pipes, 1978; Eikelboom, 1975). It is not clear how filamentous organisms dominate in activated sludge. However, Godder and Forster, 1987) offered a working hypothesis based on existing knowledge about the property of pure cultures of *Microthrix parvicella* and *Nocardia*. For example *M. parvicella* was shown to utilise oleic acid, and in doing so, to accumulate fatty acids. Trehalose containing glycolipids produced by *Nocardia* spp. have been shown to emulsify water-hydrocarbon mixtures and to stimulate the growth of *Nocardia* in the hydrocarbon. It is not unreasonable therefore to suggest that the presence of unemulsified lipids in the sewage being fed to an activated sludge gives *Microthrix parvicella* and *Nocardia* a metabolic advantage over other bacteria in the sludge which neither have the ability to utilize the lipids so readily nor had their growth stimulated. Under certain conditions, the actinomycetes produce a lipid material which is excreted into the mixing liquor. These lipid material collects on the surface of air bubbles, the bubbles mesh together including the actinomycete colonies, and float to the surface to form a scum (Pipes, 1978)

Cairns *et al.* (1982) found that *Nocardia amarae*, a very common foam actinomycete, is able to deal with oil in water emulsions. The oil droplets formed thereby can serve as selective food supply. By their ability to emulsify and de-emulsify and the possibility to grow on grease; and because of the hydrophobic cell walls, actinomycetes have an advantage in competing for such substrates. High grease and oil contents of the primary influent to the treatment plants can sometimes trigger an excess actinomycete biomass production. In a parallel study conducted on the same treatment plant at the same time this investigation was performed, peak lipase activity was obtained during the time of foaming. Lipase activity patterns almost correspond to the activities of hexokinase, adenylate kinase and glyceraldehyde-3-phosphate dehydrogenase. This might have been induced by the increase of lipid content in the mixed liquor.

Branched hyphae of nocardioform bacteria may form a net between the sludge flocs, trapping oil and grease droplets or gas bubbles, thus making the sludge float to the surface (Lemmer, 1986). The high lipid content of organisms involved in foaming up to 35% of their weight reported for *Microthrix pavicella Slijkhuis* (1983) has suggested to show writers that lower density in relation to water causes fats and bacteria to rise to the surface. In a parallel study conducted on the same treatment plant, peak lipase activity was obtained during the time of foaming. Lipase activity patterns almost correspond to the activities of hexokinase, adenylate kinase and glycerinaldehyde-3-phosphate dehydrogenase (Fig. 4 - 5). This might have been induced by the increase of lipid content in the mixed liquor and consequently increased the chance for the proliferation of actinomycetes.

In a study conducted on the cause of abiotic parameters on foaming, Lemmer (1985) found no defined relationship between foaming problems and physical, chemical and technical parameters of the treatment plants. Foaming problems were found in different plants within a wide range of plant parameters and within a high variety of sewage compositions. The only common characteristics found in all plants was the enormous biomass of filamentous microorganisms, which were identified as actinomycetes in 90% of the plants. In this study too there was no obvious relationship between foaming and operational parameters of the activated sludge such as influent flow rate, BOD, COD, aeration basin dissolved oxygen. Neither did enzyme activities correlate with operational parameters.

Phosphate might have exerted an influence on the activity of the activated sludge. During the foaming time the influent phosphate was higher than normal periods of operation. The removal efficiency of phosphate was also higher during the time of foaming at which time enzyme activities were higher compared with other times. Kämpfer *et al.* (1995) studied the growth requirements of filamentous bacteria isolated from bulking and foaming sludge. Strict dependency was found for the presence of calcium, magnesium, and phosphate in the medium for all isolates (no strain grew in the absence of one of these substances). Phosphate concentration greater than 20 mg/l was required for the growth of most groups.

Although there are conflicting evidences regarding the relationship between temperature and overgrowth of organisms in the activated sludge, there is a general consensus that growth of *Nocardia* and foaming and scumming are associated with higher temperature rather than lower waste temperatures (Pitt and Jenkins, 1990). Lechevalier (1975) correlated foaming problems with temperatures above 14°C. There are also reports indicating the likely occurrence of actinomycete foams in warm climates (Soddel and Seviour, 1995; Eikelboom, 1991). In the case of Leutschach wastewater treatment plant, it appears that temperature has played a major role on change in the physiology of the microorganisms in the activated sludge system because the phenomenon occurs in the warmest season of the year. Seasonal changes in the composition of the incoming sewage may also be considered as potential cause for foaming in this activated sludge. This is plausible since it is known that many tourists come to Leutschach in June and July. The production and/or consumption of wine are expected to be high in this season. Godder and Forster (1987) indicated the susceptibility of activated sludge to foaming at autumn equinox, albeit it was not proved whether it was due to change in temperature or change in the composition of the incoming fed.

Conclusion

Early signs of foaming were indicated by changes in the hexokinase, adenylate kinase and glycerinaldehyde-3-phosphate dehydrogenase activities of the activated sludge. Generally, the activities began to increase in June reached peaks during the time of foaming in July. There was significant difference in enzyme activities between foaming and non-foaming periods. These enzymes can therefore be considered as good indicators of microbial activities in the treatment plant with respect to foaming. Eventually, appropriate control or preventive measures can be taken ahead of time based on the results of enzyme activity assays in combination with measurement of other important treatment parameters.

While this study was carried out, extracellular enzymes such as protease, dehydrogenase, esterase, alanine-aminopeptodase, a-glucosidase, lipase and b-glucosidase were also used to characterize the activated sludge from the Leutschach wastewater treatment plant. But assays of enzymes from the cell-free extract showed better correlation with foaming than extracellular enzyme assays.

Future studies should focus on: (i). Identification of the causative microorganisms involved in foaming. This will provide significant information on the cause of foaming and (ii). Determination of the composition of the incoming fed to check the possibility of seasonal variation in nutrient contents with emphasis on lipids and phosphate.

Acknowledgements

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Figure 1
Fig.1 Hexokinase activity of the activated sludge from Leutschach wastewater treatment plant.

Figure 2
Fig.2 Adenylate kinase activity of the activated sludge from Leutschach wastewater treatment plant.

Figure 3
Fig.3 Glycerinaldehyde-3-phosphate dehydrogenase activity of the activated sludge from Leutschach wastewater treatment plant.

Figure 4
Fig.4 The relationship between hexokinase and lipase activities of the activated sludge from Leutschach wastewater treatment plant.

Figure 5
Fig. 5 The relationship between glycerinaldehyde-3-phosphate dehydrogenase and lipase activities of the activated sludge from Leutschach wastewater treatment plants.

Figure 6
Fig.6 The relationship between adenylate kinase and lipase activities of the activated from Leutschach wastewater treatment plant.

Irrigation Research Technologies Recommended for Sustaining Crop Production in Some Irrigated Areas of Ethiopia.

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Abstract

Water is very essential for plant growth. It is needed for seeds to germinate, seedlings to emerge, and for plant growth and development. Water prevents the dehydration of plants, and water provides the transport mechanism for plant nutrients and the products of photosynthesis. When water for plant growth can be controlled by irrigation, average yields under comparable climatic conditions generally are higher than those obtained under rainfed conditions. The difference in yields between irrigated and non-irrigated lands is greatest during seasons that have periods of drought and above normal evaporative demands. Because yields on irrigated lands are higher and more consistent, irrigation plays a major role in stabilizing food and fiber production.

The aim of this paper is to present various experimental outputs on irrigation water management and practices developed for effective, efficient and sustainable agricultural development. All of the outputs were obtained through field experiments except some, which were predicted using climatic data and computer model. Experiments were conducted using Awash River as an irrigation water source in the Awash River basin.

Introduction

In the past, irrigation enabled civilization to establish permanent home sites in semi-arid and arid lands. Today, irrigated agriculture continues to make food and fiber supplies less dependant on fluctuations in climate. Irrigation is one of the oldest known agricultural technologies, but improvements in irrigation methods and practices are still being made. The future will require even greater improvements as competition for limited water supplies continue to increase. Competition for limited water supplies will significantly affect future irrigation development and practices.

In arid areas crops require adequate irrigation to meet, ET needs, but soils must also receive additional water to leach accumulated salts from the root zone. All water obtained from surface streams or subsurface aquifers typically contain dissolved solids. Repeated irrigation leads to accumulation of salts in the root zone as plants extract nearly pure water there by concentrating the salt solution in the soil. Leaching provides a fraction of the applied water more than that which can be retained within the root zone to flush out the concentrated salts that have accumulated.

In areas where natural drainage is very limited, the water table is often controlled by cement or clay tile lines or by plastic drain tubing.

Ethiopia has a total land area of about 124 million hectares. Out of this, about 16.4 million hectares are suitable for the production of annual and perennial crops. Of the estimated arable land, about 8 million hectares is used annually for rain-fed crops(CSA,1999). Moreover, the dry land areas of Ethiopia account for more than 66.6 % of the total landmass of the country

The river basins of the country covers about 1,127, 312 km^2 in which a mean of about 112.45 X 10^{9}m^3 volume of water flows from the catchment annually. The potential gross irrigable area of the country is 2,920,130 hectare of land. The groundwater potential in the country is about 2.59 X 10^{9}m^3 (MWR, 1998). This shows that Ethiopia is endowed with water resources, which could be easily tapped and used for irrigation, and the available water resources of the country are sufficient enough to cover the demand for irrigation if the water is properly conserved.

On the other hand, Ethiopia is already suffering from food shortage because of the increasing population and chronic drought occurrence in most parts of the country. Good land and quality sources of irrigation water were fully exploited in most parts of the world. However, Ethiopia has not developed irrigation to the potential it has, i.e. according to the availability of physical resources, land and water only a little more than 3 % of the irrigable land is currently irrigated both in large and medium scale. The development of irrigated areas in the country has also been unevenly spread. Over 70 % of the area developed for irrigation to date are in the Awash River basin. Awash River, which is important for its irrigated agriculture starts in the central plateau and flows to the northeast through the rift valley.

In the semi-arid Awash basin, with the development of new areas, salinity and sodicity became a factor of new concern. Hence, the development and maintenance of successful irrigation practice involves not only the supplying of irrigation water to the land but also the control of land degradation, i.e. salinity, sodicity and rising water table

One of the research agenda of the research system of Ethiopia is to develop research technologies on crop water requirement of various potential crops for efficient utilization of land and water resources and to develop appropriate technologies for arresting environmental degradation. Based on this, various research recommendations on irrigation, drainage and land reclamation was developed and presented below.

Materials and Methods

1. Crop water use studies
2. Land reclamation
3. Irrigation method

1. Crop water use studies

a) Field experiment

Different irrigation regimes (amount and frequency) were under treatment in randomized complete block (RCBD) design. The experiment was conducted in major irrigated areas of the country under large- scale conditions. This was done for the determination of optimum water requirement of some selected crops in a given period of time.The required amount of water measured with 3-inch partial flume was applied to each plot according to the experimental treatments. Soil moisture was recorded from different soil depth before and after irrigation for uniform water distribution monitoring. Rainfall data was recorded from the near by weather station for the follow up of given irrigation frequency. Agronomic data (plant height, seed weight, seed yield etc.) were recorded. Water use efficiency was calculated using the amount of applied water and crop yield obtained for each of the experiments.

b) Modified pen man method

Potential evapotranspiration was calculated using modified penman equation. The input data used for this analysis was meteorological parameters from the near by weather station of each site. Crop evapotranspiration was determined with the following formula for each crop

$$ET_{crop} = Kc \times ETo$$

The net and gross irrigation water requirements were also determined for each crop.

2) Land Reclamation:

The land reclamation methods used for the reclamation of salt affected soils and high groundwater areas in the Middle Awash Valley were:

a) Subsurface drainage
b) Leaching

a)Subsurface drainage:

Subsurface drainage system was installed to reclaim the salt affected soils and intercept the rising groundwater table on pilot drainage scheme. The experimental treatments which were under treatment were different drain spacing (20 m, 40 m, 60 m and 75 m) and to evaluate different filter / envelope materials. Testing of envelope materials were conducted at 40 m drain spacing. The test crop for drain spacing trial was cotton and for that of envelope materials banana. Collector drains were constructed on the lower side of the scheme. Irrigation water was applied for each plots following the recommended irrigation regime of the given test crops. Soil samples were taken for the monitoring of salinity / sodicity hazard. The sample was analyzed for ECe, PH, cation and anions determination in the laboratory. A number of pezometers were installed at different spots for the observation of groundwater table fluctuation. Drain water was collected from each lateral and analyzed for electrical conductivity and pH.

b) Leaching:

Leaching experiments were carried out under 10 m X 10 m basin to leach down the soluble salts. The plots were without crops for the purpose of free leaching practice.

The land was first sub-soiled, leveled and soil bunds, irrigation canals and surface drains were constructed. Graduated sticks were installed on each plot to measure the applied water. The experimental design was randomized complete block (RCB) with 4 replications. A total of 16 plots were under treatment. The experimental treatments were continuous and intermittent ponding of water with 150 mm and 200 mm water applied.

In the continuous ponding water level was replenished as the level reduces every day to maintain the initial level. In the intermittent plots water was applied as the water recedes from the plots. Soil samples were taken from different soil depths of each plot.The samples were analyzed for ECe, pH, cations and anions determination. In-stitu measurement of electrical conductivity of the soil was taken with portable conductivity meter.

3)Irrigation method (Furrow evaluation)

The land was prepared and properly leveled. Conventional furrows with 80 cm spacing, 400 m length and different slops were constructed. Wooden pegs were stationed every 25 m of each furrow. Alternate furrows were used for the evaluation. Different stream sizes were maintained for each furrow. The required water was siphoned from the irrigation canal to each alternate system furrows. The required parameters such as advance time, cutback stream, recession period and run-off were recorded.

Results:

Research technologies on agricultural water management studies in some irrigated areas of Ethiopia

Middle Awash:

Middle Awash is found in Semi-arid climatic zone with a long hot summer and a short mild winter. The annual rainfall is 200 to 600 mm. The soils of the research center are 70 % vertisol and 30 % fluvisols. Where as, The soils of the Middle Awash valley as a whole is the reverse.

Cotton:

"The optimum sowing dates for cotton in the Middle Awash region is between 1 to 15 May.

"Optimum irrigation regime for cotton in the Middle Awash has been found to be 75 mm per application every 2-weeks or 125-mm per application every 3-weeks.

"Suitable irrigation system is furrow irrigation with one establishment irrigation of 150 mm.

"Cotton water yield relations were established with 150- mm irrigation water at squaring, flowering and boll formation stages each with two establishing irrigation of 150 mm under Middle Awash condition.

"Pre-irrigation (150 –mm) practice for cotton was justified as an important practice for weed control, germination, and high crop yield.

Kenaf:

"Usual planting time for kenaf in the Middle Awash region is around Mid-May.

"Estimated crop water requirement is 839.6 mm seasonally.

"Irrigation amount of 125 mm every 2 weeks a total of six irrigation gave high yield and water use efficiency.

"Suitable irrigation system is furrow irrigation

Groundnut:

"It has been found to grow during the main and off-season in the Middle Awash region but the crop doesn't perform well during the off season.

"Maximum yields of 69.5 qt/ha were obtained when irrigation was given every 2 weeks at the rate of 125 mm and 75 mm per application.

"The crop water requirement estimated using modified penman method for a crop planted on may 15 and with a 150-day growing period was 801.55 mm.

"The optimum irrigation regime of 3-weekly application of 125 mm gave a net seasonal irrigation requirement of 775-mm comprising 150 mm at planting followed by five irrigation up to 120 days.

"Taking in to consideration the effective seasonal rainfall during the cropping season, the total available water for this crop under the recommended irrigation regime would be 950 mm.

"Gross irrigation requirement for groundnut in the Middle Awash region will be around 1080 mm assuming irrigation efficiency.

"Three- irrigation at pre-flowering, peak flowering and pod development gave highest yield.

"Two irrigation at peak flowering and pod development yielded nearly equal.

"Recommendations: Three irrigation at;

"Pre-flowering

"Peak flowering

"Pod development

"Recommendation was 150 m at plant establishment and 125 mm every 21 days up to 105 days.

"Suitable irrigation system is furrow irrigation

Sesame:

"Early July and early November planting were optimal for the main and minor seasons respectively.

"In both seasons, yield depressions were observed that as the sowing dates were delayed beyond July and November.

"The different irrigation regime did not significantly affect a 3-week frequency and 100- mm application is commonly practiced.

"With an irrigation regime of 100 mm every 3-weeks the net seasonal irrigation requirement is 450 mm , comprising a 150 mm application at planting followed by 3-irrigation up to 63 days from planting sesame irrigation system.

"The most suitable irrigation system for sesame is:

"10 m wide X 140 m long border irrigation

"Slope 0.1 of along the flow

"The border irrigation system was considered most suitable for the following reasons.

"Low labor requirement

"Simplicity of operation

"Simplicity of seeding and cultivating by machinery

"Possibility of mechanical harvesting by using a reaper binder.

"Recommendation was 100 mm every 21 days until 63 days after sowing

Wheat:

"Recommendation was given for wheat as 100-mm irrigation water every 10 days.

"Three irrigation with 125 mm each at Tillering, booting and grain filling period; or Tillering, jointing and grain filling period, or Tillering, anthesis and grain filling period is recommended for wheat crop under Middle Awash condition.

Maize:

"A sowing date experiment carried out during the main and minor-cropping seasons revealed that the optimum date of planting during the main season was June.

"November planting was found to be optimum for the cool season.

"Maximum yield of 56.3 q/ha was obtained when an application of 125 mm every week.

"Similar yield (51.2 q/ha) was obtained when an application of 125 mm every 2 weeks

"Looking into water use efficiency and crop yield irrigation water application of 125 mm every 2-weeks.

"Since maize is a relatively shallow rooted crop, it is particularly sensitive to shortage of moisture and the time of irrigation is critical. The time at which irrigation is given appears more important than the amount of irrigation.

" It was found that there was no advantage in extending the irrigation beyond 84 days after planting.

" The estimated crop water requirement for crop planted on first of November is 611.3 mm, which is not greatly different from crops planted in July.

"With an irrigation application of 75 mm every 2 weeks the net seasonal irrigation requirement is 600 mm, comprising a 150 mm application at planting and 7 to 8 irrigation.

"The gross irrigation requirement for maize planted in November in the Middle Awash region ranges from 840 to 900 mm.

"Three irrigation of 150 mm at vegetative, tasseling and grain development is also recommended.

Banana:

"The water use efficiency and fruit yield were the highest for an irrigation regime of 2-week frequency and 100 mm application.

"The irrigation requirement under this regime is 1700 mm for a period of 10 months (April to January) resulted in an annual irrigation requirement of 2028 mm. With an effective rainfall of about 430 mm /year, the annual total water use will be around 2450 mm.

"Based on the modified penman method, the seasonal crop water requirement for banana is 1843 mm / year and, with 75 % irrigation efficiency and an 8 % leaching requirement, the gross irrigation requirement is about 3071.7 mm per annum.

Sweet pepper:

"Sweet pepper is well adapted for growing in the Middle Awash Valley

"The highest yields and water use efficiencies were obtained under an irrigation regime of 6 days intervals and 40 mm application.

"With this regime, a total of 810 mm of water is required for one cropping season.

"The estimated crop water requirement of the crop during August to December is 802.78 mm and the gross irrigation requirement assuming 8 % leaching requirement and 75 % irrigation efficiency is 1090 mm.

Onion:

¨Onion can be grown successfully during the major and minor cropping seasons.

¨In a 3-year experiment conducted at Werer, the crop was found to respond better to irrigation at frequent rater than prolonged intervals.

¨Yield of onion tends to decrease as the frequency between irrigation increase and increases with an increase of water duty.

¨Maximum fresh bulb yield was recorded for an irrigation regime of one-week frequency and 50 mm application.

¨The crop water requirement of onion, as estimated using the modified penman method, is 516.87 mm for crops planted in October and growing for 120 days.

¨With irrigation regime of 50 mm applied weekly the net irrigation requirement ranges between 850 and 900-mm and the gross irrigation requirement ranges between 1100 and 1200 mm.

Alfalfa:

¨Alfalfa is well adapted as a lowland pasture and can be grown under irrigation.

¨Alfalfa was found to respond best to shorter irrigation intervals and at higher rates of water application.

¨The maximum yield was obtained with an irrigation regime of one-week and 100 mm application.

¨In terms of water use efficiency, both one week and 50 mm application and 2-week frequency and 100 mm application are equally important.

¨From the management point of view, 2-week frequency and 100 mm application is optimum regime.

¨The net irrigation requirement under this regime is 6300 mm, 26 mm per month

¨Using modified penman for a growing period of 365 days the crop requirement is 2273.65 mm.

¨The net irrigation requirement for an irrigation regime of 2-weeks and 100 mm application is 2700 mm.

Gode:

Groundnut:

¨Maximum yield was obtained under an irrigation interval of 6 days and 150 mm per application

¨Recommendation was 100 mm every 6 days

Sesame:

¨Shorter irrigation intervals (7-14 days) were better than longer ones

¨Heavier water applications (10 – 15 cm) were better than application of 5 cm.

¨Maximum yield of 13.6 q/ha was obtained for an irrigation regime of 2 weeks and 15 cm application.

¨Recommendation was 100 – 150 mm every 14 days

Tendaho:

Cotton:

¨Yield declined progressively as irrigation frequency was increased from 2 to 4 weeks and increased with an increase of water application.

¨Yield depression was also observed when irrigation was prolonged beyond 120 days.

¨Weekly irrigation application gave the highest yields. This is because of high evapotranspiration.

¨Recommendation was 100 to 125 mm of irrigation water every week.

Arba Minch:

Cotton:

¨Recommendation 125 mm every three weeks.

Gewane:

Cotton:

¨Recommendation was 175 mm irrigation water every 3-week intervals.

Drainage and Reclamation

¨Intermittent leaching method with single application of 200-mm water depth every recession period could be applied for cotton crop as a free leaching practice for reclaiming salt-affected soil with sub-surface drainage pipe under Middle Awash condition.

¨Sub-surface drainage system is effective in controlling ground water table depth and soil salinity level under Middle Awash condition with the following components:

¨Corrugated plastic pipes (PVC) with 60 and 80 mm nominal diameter.

¨Red-ash as envelope material

Crop	Amount (mm)	Frequency	Location
Cotton	75 – 100	2 weeks	Middle Awash
	125 - 150	3 weeks	Middle Awash
	100	2 weeks	Lower Awash (Tendaho)
	125	3 weeks	Gewane
	80	3 weeks	Upper Awash (Merti-Jeju)
	125	3 weeks	Arba-Minch
Groundnut	100	2 weeks	Middle Awash
	150	3 weeks	Middle Awash
Sesame	100	2 weeks	Middle Awash
Maize	100 – 125	1 week	Middle Awash
	150 – 175	2 weeks	Middle Awash
Wheat	100	10 days	Middle Awash
Kenaf	125	2 weeks	Middle Awash
Banana	100	2 weeks	Middle Awash
Onion	50	1 week	Middle Awash
Tomato	90	1 week	Middle Awash
Citrus	50	2 weeks	Middle Awash
Alfalfa	150	2 weeks	Middle Awash

Table 1. Summary of irrigation requirements of some lowland crops

Table 2. Physical properties of two main soil types of Middle Awash Region

Properties	Dark vertisols	Brown alluvial
Color	Dark Grey when dry, black when wet	Light brown when dry, dark brown when wet
Texture	Silty – clay to clay	Sandy-loam to silty-loam
Consistency	Very sticky when wet Very hard when dry	Moderately sticky when wet, moderately hard when dry
Volume change	Swells when wet, shrinks & develops large crack when dry	Moderate expansion
Basic infiltration rate, mm/hr	5 – 7	10 – 15
Field capacity (%)	46.00	35.70
Permanent wilting point(%)	30.40	19.55
Available soil moisture Dry weight basis %	15.60	16.55
Bulk density, g/ cm^3	1.17	1.33
Pore space, %	50.20	44.2

Source: G.Haider, 1986, review of soil and water management research

Table: Optimum stream flow rates and furrow lengths

Characteristics	Location		
	Werer center	Melka Sedi	Amibara
Optimum initial stream flow rate (liters/sec.)	3.44	2.34	3.50
Cut-back stream flow rate (liters/sec)	0.72	1.72	1.42
Optimum furrow length(m)	205.00	190.00	210.00
Application efficiency %	97.00	78.00	62.00

"Drain spacing of 40 to 60 m

"Drain depth of 1.7 to 2.0 m

"In the Middle Awash Valley, where evapotranspiration is greatly exceeding precipitation, it is advisable to keep the land wet under continuos cropping to avoid movement of salt to the surface from shallow ground water in course of alternate wetting and drying.

Future Research Focus/ direction

1.Inventorize, characterize, test and improve indigenous knowledge / traditional practices of agricultural water management.

2.Research attention on small scale irrigation practices (Irrigation regimes (amount, frequency) irrigation methods etc)

3.Supplementary irrigation using rainwater harvesting techniques (spate irrigation)

4.Studies on ground water irrigation (surface, pressurized)

5.Evaluation of more efficient irrigation methods (sprinkler, drip)

6.Development of water saving technologies.

7.Develop and strengthen adaptive research using already developed technologies

8.Research on different drainage techniques (surface, subsurface, mole etc.) for the establishment of design criteria.

9.Research on problem soils (water logged, saline /sodic soils)

10.Development of watershed management technologies

11.Development of appropriate and environmentally friendly technologies for sustained use of wet lands (marshy/ swampy)

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Diurnal Characteristics of August Heavy Hourly Precipitation for Selected Stations in the Awash River Basin

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Abstract

August hourly precipitation data of four stations in the Awash River Basin were analyzed using the traditional time series method. The heavy hourly precipitation were categorized into four categories (2.5-5mm/h, >5-12mm/h, >12-20mm/h and >20mm/h). The study shows that different categories prefer certain time of the day for their occurrence, and it is found that most of the heavy precipitation events occur between noontime and midnight after the time of maximum boundary layer heating and after the formation of convective systems.

Introduction

Investigation of the diurnal characteristics of precipitation is a very long generated point of scrutiny for many researchers. Literature reviews indicate that numerous studies conducted at different places related to this topic by different researchers. In spite of its popularity very little has been done in Ethiopia. Recently Tesfaye and Endalkachew (1996) conducted a frequency analysis of hourly precipitation for selected stations in the Awash Basin. Such studies will help in determination of the time of the day at which heavy precipitation is most likely to occur and can help to identify and forecast the time of the day of greatest threat of flash flood.

The aim of this study is to investigate the diurnal characteristics of august heavy hourly precipitation for four stations in the Awash River Basin namely: Addis Ababa, Combolcha, Dixis and Kulumsa (Figure 1). The study expands the understanding of the characteristics of hourly precipitation in the Awash Basin. It will identify the time of the day of heavy hourly precipitation for the month of August. The study is limited to the availability of computer accessible data. The four stations among the others are selected because they contain relatively continuous ten and more years data. The month of August is selected not only because it is computer accessible data but also it is known that most flash flood in the basin occurs in August and September.

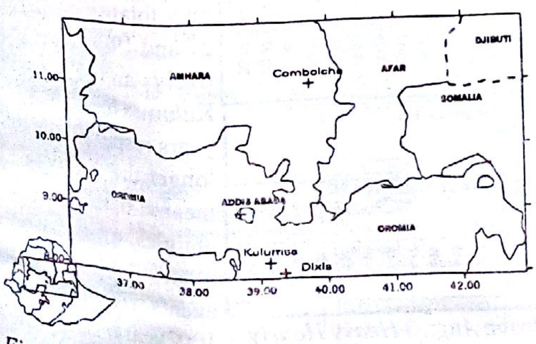

Figure 1 Stations Location Map (identified by + sign)

2- Basin and Data Description

2.1 Basin description

Awash River is the principal river of the Ethiopian section of the Great Rift Valley, and is highly utilized for hydroelectric power generation and irrigation purposes. The River Basin has a surface area of 113,709km², which lies between the latitude of 8°N and 12°N on the southern and northern sides of the central plateau of Ethiopia. There is a wide elevation variations ranging between 250m and 3000m above mean sea level. Most part of the basin lies geologically within the Great Rift Valley. The Basin is divided into four parts: Upper Basin, Upper valley, Middle Valley, and lower plain (FAO 1965). The Basin's climate varies from Arid part of the downstream lowlands at the far end of the basin to Humid sub-tropical of the central plateau of Ethiopia (Gonfa, 1996: Abebe 1998).

The middle valley of the basin has good climate and soil, and is extensively used for agriculture activities. The lower plain area is less favorable for agriculture activities and highly exposed for flooding problems. Since most of the huge industries of the country, the capital city Addis Ababa and other large towns are located inside the basin, there are wide settlements. The middle valley and lower plain of the basin is annually exposed to frequent flooding those cause extensive damages to properties and life.

2-2 Data Description

The August hourly precipitation data for the four stations were used to study the diurnal characteristics of heavy hourly precipitation. The length of the data varies from station to station and there are some missing data between the study periods (Table1). No attempt has been made to fill in the missing data.

STATION	STUDY PERIOD	DATA AVAILABLE	DATA MISSING
Addis Ababa	1968-1987	12 years	7 years
Combolcha	1966-1993	17 years	10 years
Kulumsa	1983-1992	10 years	
Dixis	1982-1992	10 years	1 year

Table 1 Data Summary

The amount, date/year, and hour of the maximum of heavy hourly precipitation for each station during the study periods are listed in table 2.

Station	Precipitation Rate mm/h	Date/Year	Hour
Addis Ababa	21.4	02/1980	13-14
Combolcha	43.5	18/1981	22-23
Dixis	58.0	07/1983	21-22
Kulumsa	18.4	24/1991	6-7

Table 2 Maximum of Heavy hourly Precipitation

3- Methodology

In this study the maximum hourly precipitation recorded during the study periods is retained for analysis. The diurnal characteristics of heavy precipitation have been identified from time series of hourly precipitation at the given stations. This is a traditional method of characteristic study of hourly precipitation. Therefore the time series of the maximum and average heavy hourly precipitation, and the annual time series of the maximum hourly precipitation were studied. To have further insight into the characteristics of the heavy hourly precipitation, the heavy precipitation events are categorized into four categories (Table 3). Frequencies of occurrences of each category during each study period were studied.

Category	Precipitation rate (mm/h)
1	2.5-5
2	>5-12
3	>12-20
4	>20

Table 3 Definition of Different Categories

4- Results and Discussions

a) Time series of maximum heavy hourly precipitation

Time series of maximum heavy hourly precipitation for the four stations are shown in figure 2. From the figure is observed that for Addis Ababa and Combolcha the maximum hourly precipitation seem to occur in the late morning to midnight hours, and for Dixis it seems that the maximum hourly precipitation likely to occur in the evening time. For Kulumsa there is no distinct pattern, but the maximum hourly precipitation seems to decline from the morning hours to the evening hours. Generally the plots indicate that extreme hourly precipitation are most likely to occur between the noontime and early morning hours that is after the time of maximum boundary layer heating and after the formation of convective systems.

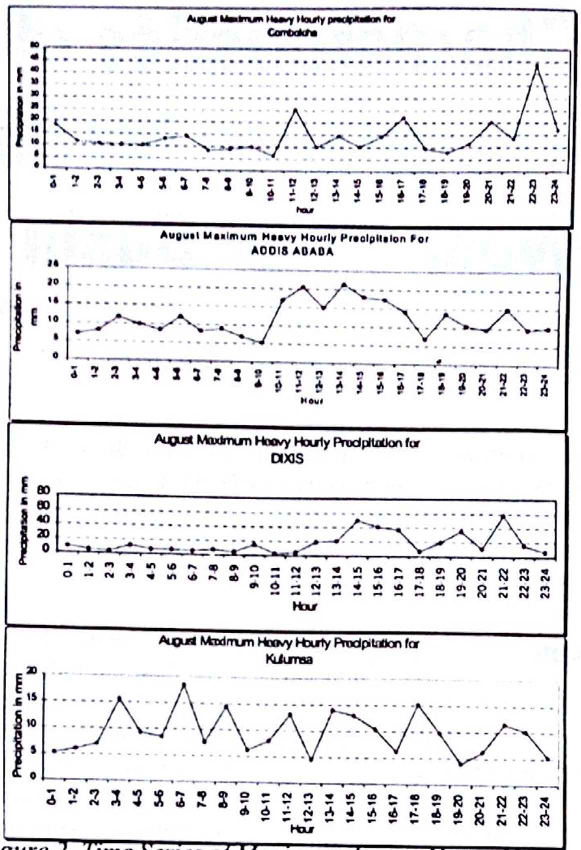

Figure 2. Time Series of Maximum August Heavy Hourly Precipitation for Combolcha, Addis Ababa, Dixis, and Kulumsa

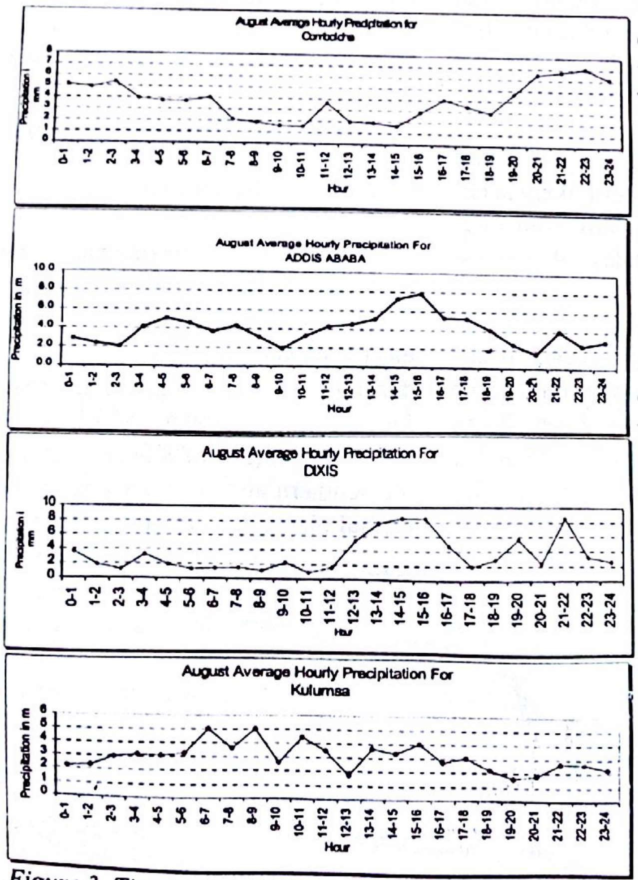

Figure 3. Time Series of Average August Heavy Hourly Precipitation for Combolcha, Addis Ababa, Dixis, and Kulumsa

b) Time Series of Average Heavy Hourly Precipitation

Time series of average heavy hourly precipitation for the four stations are shown in figure 3. The average heavy hourly precipitation for Combolcha exhibits the maximum hourly precipitation between the late night and early morning hours. Whereas Kulumsa's average heavy hourly precipitation attains its maximum amount during the morning to late afternoon hours. Addis Ababa and Dixis have their maximum average value between noon and evening hours. When this figure is compared with that of fig. 2, very close resemblance is observed for Dixis and Kulumsa, but for Addis Ababa and Combolcha there are significant variations between the two plots.

The variations observed between fig. 2 and fig.3 may be caused due to the variation in the total duration of the study periods. Combolcha and Addis Ababa have relatively long total study periods 27 and 19 years respectively and Dixis and Kulumsa have 11 and 10 years respectively. The longer the study period means that the probabilities of the occurrences of extreme events with 25-, 50-, or 100- year return periods are most likely. There fore, the time series for maximum events is different from the time series for the average events.

C) Annual Time Series of Maximum Heavy Hourly Precipitation

The time series of annual maximum of heavy hourly precipitation is shown in figure 4. Stations to the south (Kulumsa and Dixis) are indicating increasing linear trend, while stations to the north (Addis Ababa and Combolcha) are showing declining linear trends. Abebe (1998) observed such trends in annual rainfalls in his study of the Climatic Aspects of the Ethiopian Rift valley. He found an increasing trend for stations in Middle Awash Basin and increasing trends for stations in Lower and Upper Basins of Awash. The attribute given to such variation is the significant climate variability in the region (NMSA, 1996).

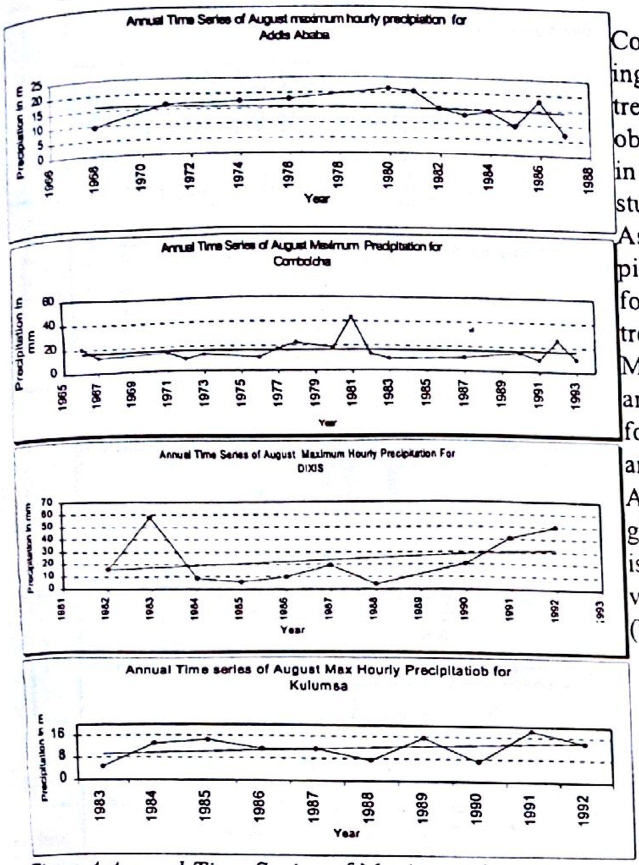

Figure 4 Annual Time Series of Maximum August Hourly Precipitation for Addis Ababa, Combolcha, Dixis and Kulumsa

D) Frequency of Occurrences of Different Categories

Frequencies of occurrences for categories listed in Table 2 are depicted in figure 5 to 8. These graphs indicate that different categories of heavy hourly precipitation prefer certain time of the day for their occurrences. The most frequent hours for each category is summarized in table 4.

ADDIS ABABA 23-10 (evening to late morning) 11-15 (noontime to mid afternoon) 12-19 (noon to evening) 21-1(late evening to after midnight) 3-11 (late night to late morning) 10 -17 (late morning to late afternoon) 11-14 (noon to mid afternoon)

COMBOLCHA20-10 (Evening to late morning) 15-9 (mid afternoon to morning) 20-1 (evening to after midnight) 5-7 (early morning) 11-17 (noon to late afternoon) 11-23 (noon to midnight)

DIXIS 0-5(night) 8-12(morning to noon) 13-23(afternoon to around midnight) 6-12 (morning to noon)19-2(evening to after mid night) 12-16(noon to mid afternoon) 3-8 (late night to morning) 12-16 (noon to midnight) 13-22 (afternoon to late evening)

KULUMSA 23-17(midnight to late afternoon) 18-22 (evening to late evening)20-12 (evening to noon) 13-19 (afternoon to early evening) 6 - 18 (day time) none

Station	Category1	Category2	Category3	Category 4
ADDIS ABABA	23-10 (evening to late morning) 11-15 (noontime to mid afternoon)	12-19 (noon to evening) 21-1(late evening to after midnight) 3-11 (late night to late morning)	10 -17 (late morning to late afternoon)	11-14 (noon to mid afternoon)
COMBOLCHA	20-10 (Evening to late morning)	15-9 (mid afternoon to morning)	20-1 (evening to after midnight) 5-7 (early morning) 11-17 (noon to late afternoon)	11-23 (noon to midnight)
DIXIS	0-5(night) 8-12(morning to noon) 13-23(afternoon to around midnight) 6-12 (morning to noon)	19-2(evening to after mid night) 12-16(noon to mid afternoon) 3-8 (late night to morning)	12-16 (noon to midnight)	13-22 (afternoon to late evening)
KULUMSA	23-17(midnight to late afternoon) 18-22 (evening to late evening)	20-12 (evening to noon) 13-19 (afternoon to early evening)	6-18 (day time)	none

Table 4 Summary of Most Frequent hours for Different categories

Generally Category 1 and Category 2 (fig 5 & 6) are distributed through out the day but most frequent after noontime to early morning hours. Category 3 and Category 4 (fig. 7 & 8) occur between noontime to midnight.

When the four categories are reduced to two categories, (category 1 + category 2 i.e. 2.5-12mm/h) and (Category 3 +category 4 i.e. >12mm/h), frequencies graphs show distinct patterns (Figure 9 and 10). Category 1 and 2 graphs for Addis Ababa and Combolcha show clear envelopes of frequencies. For Addis Ababa, it was observed three envelopes between 11-20, 21-2, and 3-11 hours, and for Combolcha it is observed two continuous hips peaked at 21-22 hour and 1-2 hours.

For Dixis and Kulumsa we don't observe such clear pattern, however for Dixis category 1 & 2 is most frequent between noon and early morning and Kulumsa has between midnight and noon.

Category 3 and 4 (figure 10) for Addis Ababa is concentrated between late morning and late afternoon, while for Combolcha, it is found between evening and midnight, early morning, and noon to late afternoon hours. For Dixis it is between noon and midnight, and in the evening. Kulumsa has no category 4.

A possible explanation given for the significant difference in the diurnal characteristics between Category 1 &2 and category 3&4 is that different processes are responsible for light precipitation events than for heavier hourly precipitation amounts. Alternatively for the occurrence of intense precipitation synoptic and mesoscale circulation patterns play less significant role as compared to local convective activities.

5- Conclusion

The goal of this study was to investigate the characteristics of heavy hourly precipitation of four stations in the Awash Basin. The major findings are summarized as follows:

Most of the heavy hourly precipitation events are occurring between noontime and midnight, this is as the result of the daily boundary layer heating cycle plays significant role in initiating and intensifying convection, and a pronounced afternoon maximum becomes established.

The markedly different characteristics of category 1 &2 precipitation rates compared to category 3&4 lead to the conclusion that different mechanisms play roles in the occurrence of the two categories. Perhaps this can be resolved if different category definitions are used for heavy hourly precipitation.

The observed annual time series trends of the maximum hourly precipitation require further investigation than attributing the climate variability as their cause.

6- Recommendations

From this study one can observe some interesting features of the diurnal hourly precipitation. Expanding such studies for other stations in the basin and throughout the country will enhance early warning and flood-forecasting services. The result may be improved if the meteorological data are analyzed together with the hydrological data and if more advanced methods are employed.

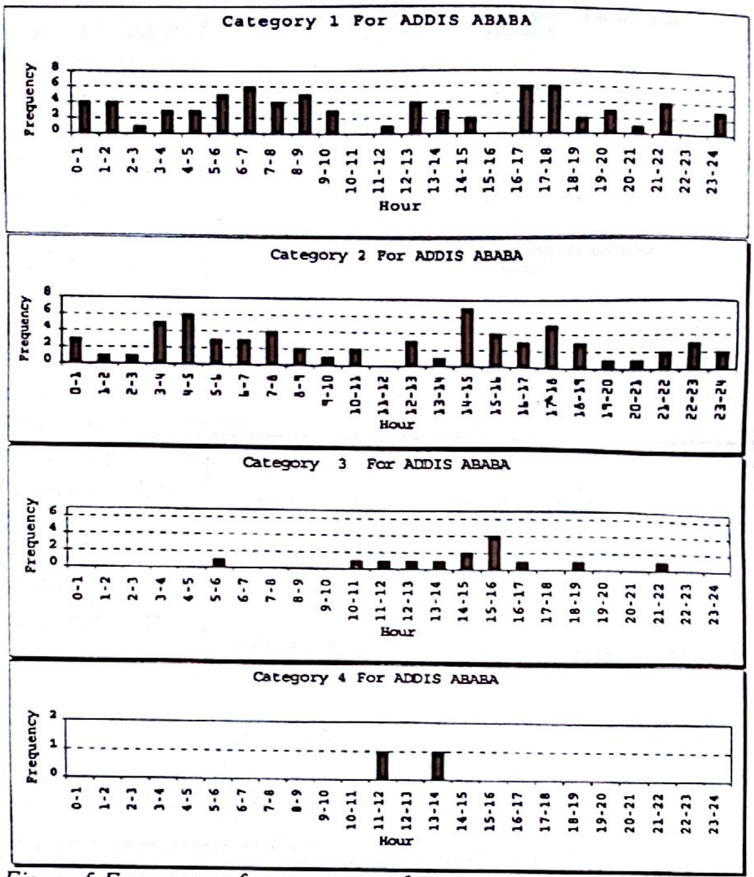

Figure 5 Frequency of occurrences of category 1 to 4 for Addis Ababa

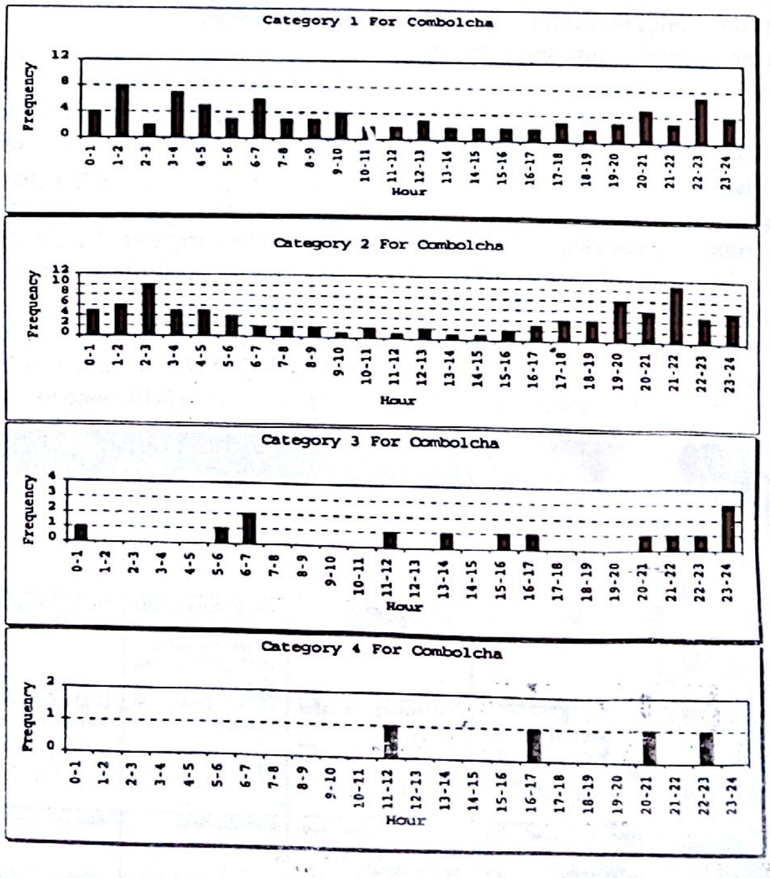

Figure 6 Frequency of occurrences of category 1 to 4 for Combolcha

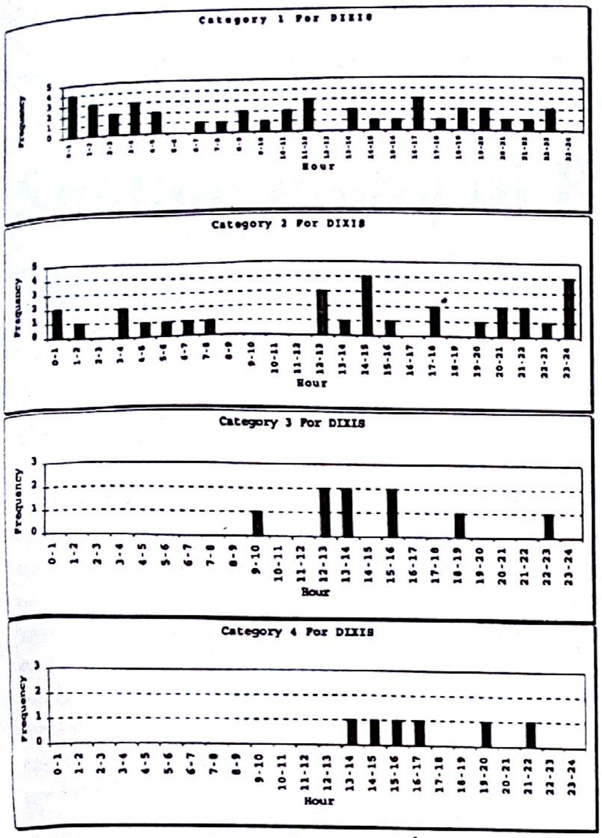

Figure 7 Frequency of occurrences of category 1 to 4 for Dixis

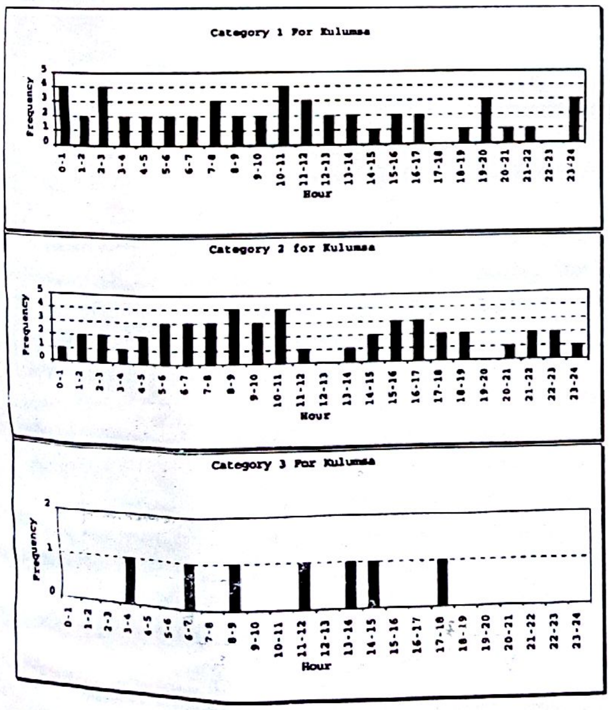

Figure 8 Frequency of occurrences of category 1 to 3 for Kulumsa. There is no category 4 for Kulumsa

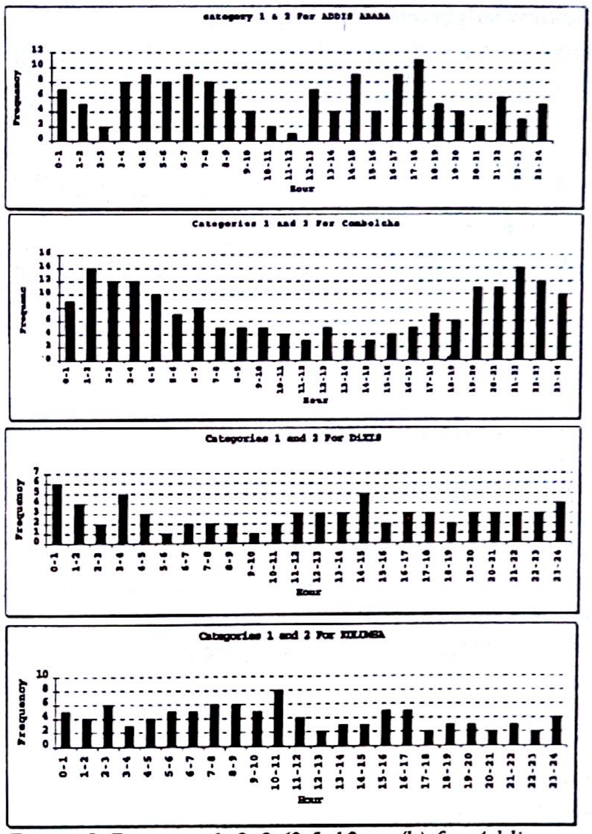

Figure 9 Category 1 & 2 (2.5-12mm/h) for Addis Ababa, Combolcha, Dixis, and Kulumsa

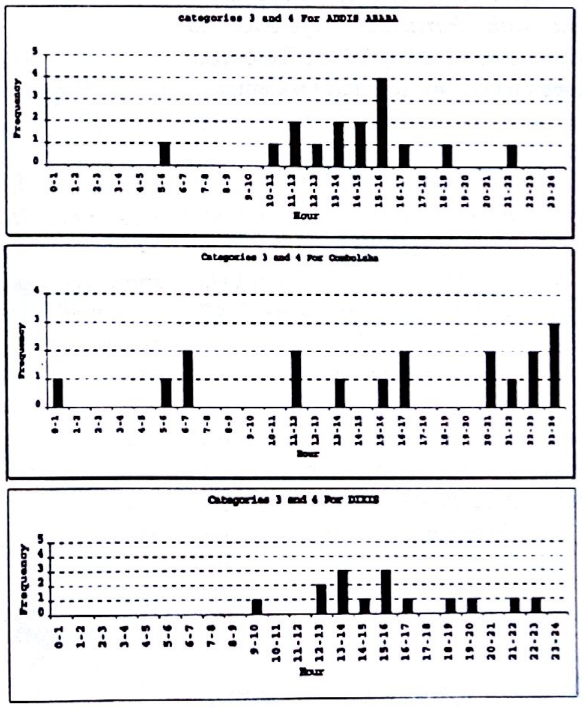

Figure 10 Category 3 & 4 (>12mm/h) For Addis Ababa, Combolcha, and Dixis. There is no category 4 for Kulumsa

Acknowledgement: I am very much indebted to the General Manager of NMSA, Ato Bekuretsion Kasahun for facilitating the conditions for this study. I would like also to express my gratitude to Ato Demlew Aweke, Development Meteorology Department Head. My special thanks go to Ato Tesfaye Gissla, Ato Melese, Ato Teferi, and Ato Kinfe for providing me the data and software for this work.

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Dry-Spell Analysis for Studying the Sustainability of Rain-Fed Agriculture in Ethiopia: The Case of the Arbaminch Area

Abebe Belachew AWTI

Abstract

Several severe droughts (prolonged dry-spells) have occurred in Ethiopia in the last three decades that have caused considerable damage to rain-fed agriculture. Consequently, severe famines occurred which have greatly affected the lives of several people and also hampered the country's socio-economic development. In this paper, it has been tried to show the practical application of dry-spell analysis on long records of daily rainfall data (25 years) for justifying the failure of rain-fed agriculture in semi-arid and arid areas of the country. The case of the Arbaminch area is presented for two commonly grown crops (maize & cotton) at two sites – the Arbaminch State Farm (with clay-loam predominant soil type) and the Kola Shara Farmers' Farmland (with silt-clay predominant soil type). The frequency of occurrences of dry-spells of duration greater than 13 & 17 days, which already causes crop failure for maize & cotton crops, have a probability of 94% & 79% in the main rainy season at the Kola Shara Farmers' Farmland, respectively. The corresponding results for the Arbaminch State Farm are 16 & 21 days dry-spell duration and a probability of 70% & 45%, respectively. One could conclude from these results that rain-fed agriculture in the area is virtually impossible without supplementary irrigation. The procedure could be applied to different parts of the country and maps could be established for different crops. When irrigation is considered as a solution, there is problem of adequate water resources availability in semi-arid and arid areas of the country. Moreover, the wettest part of the country and more than 60% of the country's 3.5 million hectares potential irrigation land is found in the Ethiopian portion of the Nile River Basin. Therefore, Ethiopia will be forced to implement the small-scale, medium-scale and some of the large-scale irrigation projects identified in the various integrated watershed management studies of the Ethiopian portion of the Nile River Basin in order to avert the loss of lives of its citizens by frequently occurring famines. In this regard, sincere and sustainable consideration of the problem and full cooperation from the international community, the downstream riparian states of the Nile River Basin in particular, is essential.

Introduction

The study area selected to illustrate the methodology is the Arbaminch area (Fig. 1). Arbaminch is located at the East floor of the southern part of the East African Rift Valley between 6°30'N to 6°08'N latitude and 37°33'E to 37°37'E longitude. The climate of the Arbaminch area is categorized as semi-arid. The mean annual rainfall, temperature, humidity, sunshine hours are about 750mm, 25°C, 57%, 7.5 hours, respectively.

Two sites are considered in the analysis in the area. The first site is the Arbaminch State Farm (1000ha) with *clay-loam* predominant soil type and gently sloped plain topography. The second site is the Kola Shara farmers' farmland (150ha) with *silt-clay* predominant soil type and moderately sloped plain topography.

The occurrence of dry-spell has a particular relevance for rain-fed agriculture, as rainfall water is one of the major requirements for plant life in rain-fed agriculture. When spatial and/or temporal distribution of rainfall is erratic during the growing season, the crops may start to wilt and cause damage to crop yield. The extent of the damage depends on the frequency of occurrence of dry-spells of different duration, which depends on the soil moisture holding capacity and the type of crop. Hence, in addition to frequency analysis of dry-spells, assessment of soil-water-plant relationship is essential. In this regard two commonly grown crops in the area - Maize & Cotton - are considered in the analysis.

The rainfall pattern of the study area is bimodal type with a major peak in April and another smaller peak in October. There is more than 25 years (1973/74 - 1997/98) of recorded daily rainfall data at a meteorological station located in the Arbaminch State Farm. Long records of other required meteorological parameters are also available. There is also another first class meteorological station located at the Arbaminch Water Technology Institute (AWTI) campus that has records for the last 12 years. Since the two stations are very close to each other, the rainfall data analysis was done with out much difficulty. Therefore the quality of the rainfall data was carefully checked and corrected. Missing data were also completed.

Methodology

The methodology primarily requires the following two major decisions:

The mean length of the *crop season*

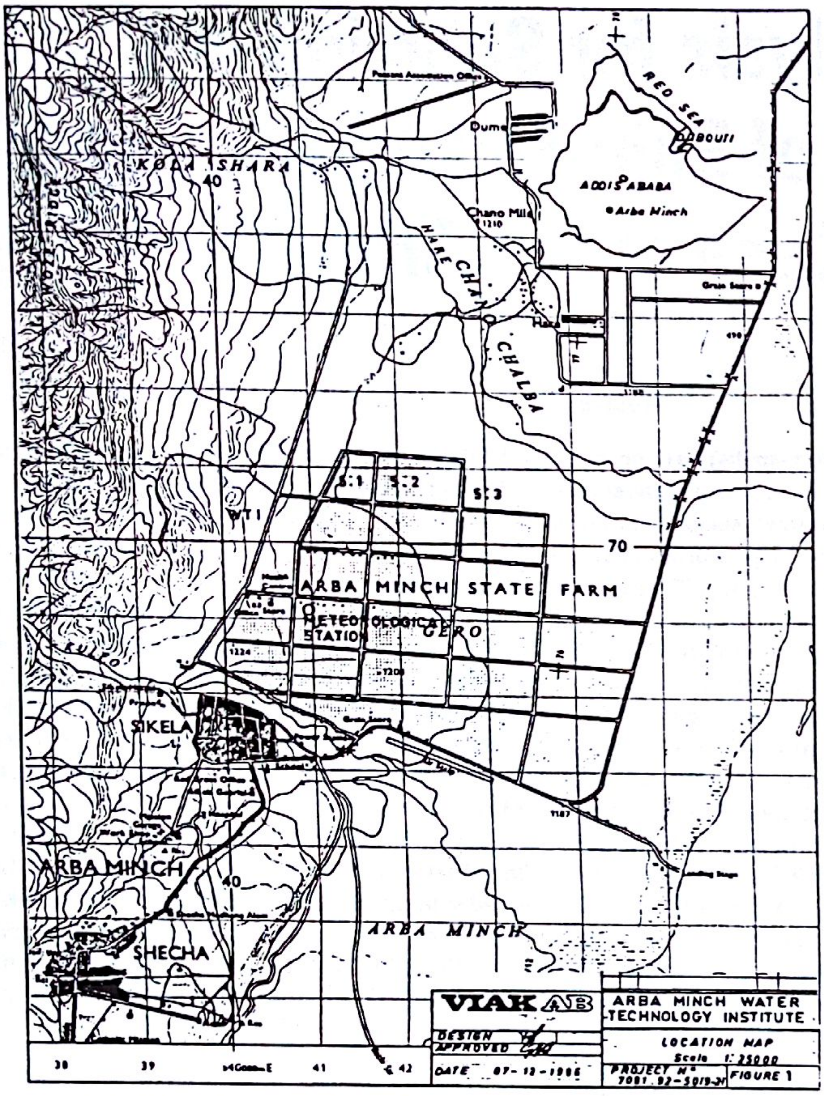

Fig.1 Location map of the Arbaminch Area (VIAK,1987)

or *crop base period* should be fixed. Based on the output from CROPWAT software and the long record rainfall trend, the crop base periods for maize & cotton are 100 days (April - July) & 150 days (April - September), respectively;

The type of predominant soil and the moisture holding characteristics must be known. The Arbaminch State Farm has *clay-loam* predominant soil type and gently sloped plain topography (VIAK, 1987). The Kola Shara farmers' farmland has *silt-clay* predominant soil type and moderately sloped plain topography (Determined by laboratory test).

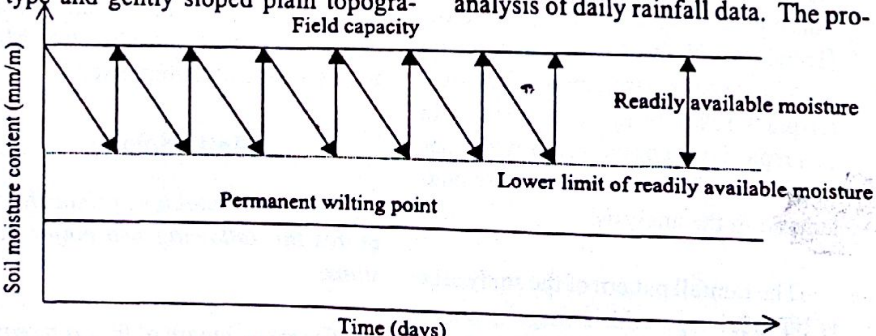

Figure 2. Frequency of Irrigation

2.1 Frequency Analysis of Dry-Spells

The occurrence of dry-spells of different duration in the crop seasons must be analyzed using frequency analysis of daily rainfall data. The procedure of the frequency analysis is similar to that applied in the establishment of flow duration curve for stream flow (Shaw, 1993). However, the procedure is quite different from those analyses involving statistical analysis of low rainfall values only.

In the **Y** years of records, the number of times **i** that a dry-spell of duration **t** days occurs will be counted. Then the number of times **I** that a dry-spell of duration longer than or equal to **t** occurs is computed through accumulation. The number of days within a crop season on which a dry-spell of duration **t** could start is computed using $n = m + 1 - t$, where **m** is the total number of days of a crop season. The total possible number of starting days is $N = n*Y$. Subsequently the probability **p** that a dry-spell starts on a certain day within the crop season is given by:

$$p = \frac{I}{N} \qquad (1)$$

Thus, the probability **q** that a dry-spell of duration longer than **t** does not occur at a certain day in the crop season is given by:

$$q = (1-p) = \left(1 - \frac{I}{N}\right) \qquad (2)$$

The probability **Q** that a dry-spell of duration longer than **t** does not occur during an entire crop season is given by:

$$Q = \left(1 - \frac{I}{N}\right)^n \qquad (3)$$

Finally, the probability that a dry-spell of duration longer than **t** does occur at least once in a crop season is given by:

$$P = (1-Q) = 1 - \left(1 - \frac{I}{N}\right)^n \qquad (4)$$

In interpreting the results of equations (1 to 4), information about soil - water - plant relationship is required to fix the duration of dry-spells (t). For the Ethiopian condition, the author recommends the following general probability

Spell duration t (days)	No. of spells i	Accum. spells I	Days per season n = 100 + 1 - t	Total No of days N = n*25	p=I/N	q=1-p	P=1-(q)^n
5	196	768	96	2400	0.32	0.68	1.00
6	144	572	95	2375	0.24	0.76	1.00
7	103	428	94	2350	0.18	0.82	1.00
8	78	325	93	2325	0.14	0.86	1.00
9	64	247	92	2300	0.11	0.89	1.00
10	51	183	91	2275	0.08	0.92	1.00
11	34	132	90	2250	0.06	0.94	1.00
12	27	98	89	2225	0.04	0.96	0.98
13	18	71	88	2200	0.03	0.97	0.94
14	13	53	87	2175	0.02	0.98	0.88
15	10	40	86	2150	0.02	0.98	0.80
16	7	30	85	2125	0.01	0.99	0.70
17	7	23	84	2100	0.01	0.99	0.60
18	6	16	83	2075	0.01	0.99	0.47
19	5	10	82	2050	0.00	1.00	0.33
20	4	5	81	2025	0.00	1.00	0.18
21	1	1	80	2000	0.00	1.00	0.04
22	0	0	79	1975	0.00	1.00	0.00
23	0	0	78	1950	0.00	1.00	0.00
24	0	0	77	1925	0.00	1.00	0.00
25	0	0	76	1900	0.00	1.00	0.00
26	0	0	75	1875	0.00	1.00	0.00
27	0	0	74	1850	0.00	1.00	0.00
28	0	0	73	1825	0.00	1.00	0.00
29	0	0	72	1800	0.00	1.00	0.00
30	0	0	71	1775	0.00	1.00	0.00

Table 1 Frequency Analysis of Different Duration of Dry-spells for Maize Crop

conditions. If P(t) is greater than 80%, rain-fed agriculture is almost impossible in the area. For 20%£P(t)£80%, rain-fed agriculture may be possible with supplementary irrigation in the area. For P(t)£20% rain-fed agriculture may be possible without supplementary irrigation in the area.

2.2 Assessment of Soil - Water - Plant Relationship

The purpose of the assessment of soil-water-plant relationships is primarily to estimate the mean frequency of irrigation. This will in turn determines the dry-spell duration longer than which will cause damage to crop yield.

The crop water requirements of the selected crops for a known soil type & characteristics must be determined. Use of software like CROPWAT is recommended. The crop water requirements needed here is the consumptive use of plants (ET_{CROP}). ET_{CROP} could be determined using empirical methods like the *modified Penman-Montieth method, Jensen-Haise method, Hargreaves method, Thornthwaite method, Balney-Criddle method, Hargreaves class A pan evaporation method, etc.*

The frequency of irrigation is then obtained using (FAO, 1992):

$$I = \frac{(p * S_a) * D}{ET_{CROP}} \quad (5)$$

Where:

p = fraction of total available soil water which can be used by the crop without affecting its transpiration and/or growth;

S_a = total available soil water or moisture (S_{FC} - S_W) in mm/m;

S_{FC} = available soil water or moisture at field capacity in mm/m;

S_W = available soil water or moisture at permanent wilting point in mm/m;

D = depth of root zone of a crop (m);

ET_{CROP} = consumptive crop water requirements.

Not all the water that is held in the root zone between S_W & S_{FC} is available to the crop (Fig. 2). The depth of water that is readily available to the crop is $p*S_a$ and it is related to the depth of application by:

$$d = \frac{(p * S_a) * D}{f_a} \quad (6)$$

Where f_a = water application efficiency (fraction). The value of ($p*S_a$) will vary with the level of evaporative demand. Since the evaporative demand varies with the growing stages of crops, ($p*S_a$) will be different with different growing stages of crops. According to mum rate to a soil-water depletion greater than that when ET_{CROP} is high (.8mm/day).

3.Results and Discussion

Based on the above procedure, the frequency analysis of the two crops was done. The results are presented in Tables 1 & 2 and Figures 3 & 4.

Based on the above procedures, the mean frequency of irrigation for maize crop are estimated to be 13 & 16 days for the Kolla Shara farmers' land & the Arbaminch State Farm, respectively. For cotton crop the corresponding values are 17 & 21 days. These values are closer to those gathered through questionnaires to the farmers' and farm experts.

The crop water requirements for maize & cotton crops have been determined using CROPWAT software (FAO, 1991). Climatic data input to CROPWAT for the Arbaminch area is

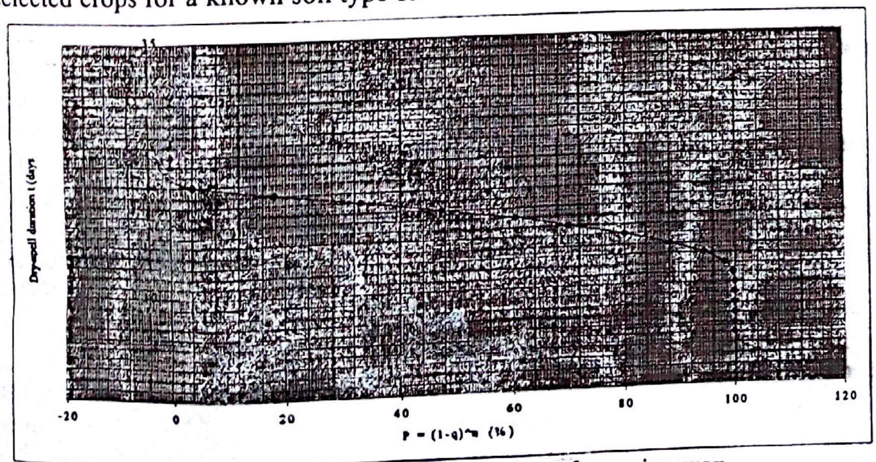

Figure 3 Dry-spell probability curve for maize crop

Spell duration t (days)	No. of spells i	Accum. spells I	Days per season n = 150 + 1 - t	Total no. of days N = n*25	p=I/N	q=1-p	P=1-(q)^n
5	255	986	146	3650	0.27	0.73	1.00
6	182	731	145	3625	0.20	0.80	1.00
7	132	550	144	3600	0.15	0.85	1.00
8	96	419	143	3575	0.12	0.88	1.00
9	79	324	142	3550	0.09	0.91	1.00
10	62	246	141	3525	0.07	0.93	1.00
11	45	184	140	3500	0.05	0.95	1.00
12	34	139	139	3475	0.04	0.96	1.00
13	24	105	138	3450	0.03	0.97	0.99
14	18	81	137	3425	0.02	0.98	0.96
15	15	63	136	3400	0.02	0.98	0.92
16	9	48	135	3375	0.01	0.99	0.86
17	8	39	134	3350	0.01	0.99	0.79
18	6	31	133	3325	0.01	0.99	0.71
19	5	25	132	3300	0.01	0.99	0.63
20	5	20	131	3275	0.01	0.99	0.55
21	2	15	130	3250	0.00	1.00	0.45
22	1	13	129	3225	0.00	1.00	0.41
23	1	12	128	3200	0.00	1.00	0.38
24	1	11	127	3175	0.00	1.00	0.36
25	1	10	126	3150	0.00	1.00	0.33
26	1	9	125	3125	0.00	1.00	0.30
27	1	8	124	3100	0.00	1.00	0.27
28	1	7	123	3075	0.00	1.00	0.24
29	1	6	122	3050	0.00	1.00	0.21
30	1	5	121	3025	0.00	1.00	0.18
31	1	4	120	3000	0.00	1.00	0.15
32	1	3	119	2975	0.00	1.00	0.11
33	1	2	118	2950	0.00	1.00	0.08
34	1	1	117	2925	0.00	1.00	0.04

Table 2 Frequency Analysis of Different Duration of Dry-spells for Cotton Crop

presented in Table 3. The resulting potential evapotranspiration determined by CROPWAT based on the Penman-Montieth method is presented in Table 4. Then, the crop water requirements are presented in Tables 5 & 6 for maize & cotton, respectively.

Table 4. Potential evapotranspiration obtained from CROPWAT

Table 5. Crop water requirements for maize crop obtained from CROPWAT

From Fig. 2, for maize crop, the probabilities that a dry-spell of duration longer than 13 & 16 days does occur at least once in a crop season are 94% & 70% at the Kolla Shara farmers' farmland & Arbaminch State Farm, respectively. From Fig. 3, for cotton crop, the probabilities that a dry-spell of duration longer than 17& 21 days does occur at least once in a crop season are 79% & 45% at the Kolla Shara farmers' farmland & Arbaminch State Farm, respectively.

One could conclude from these results that rain-fed agriculture in the area is virtually impossible without supplementary irrigation. The procedure could be applied to different parts of the country and maps could be established for different crops. When irrigation is considered as a solution, there is problem of adequate water resources availability in semi-arid and arid areas of the country.

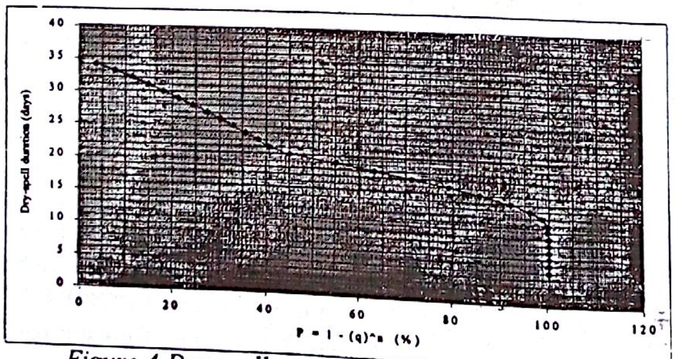

Figure 4 Dry-spell probability curve for cotton crop

Ethiopia, with a geographical area of about 113 million (km)[2], has been affected frequently by severe droughts (prolonged dry-spells) in the last four decades. This is because the large part of the country is categorized as drought prone areas (Fig. 5). About 60% of the area is potentially cultivable, with only 15% currently utilized (CSA, 1995). Moreover, the country has more than 3.5 million hectares potential irrigable land with less than 3%. The country has also about 120Bm³ surface water and about 2.6 Bm³ groundwater resources potential (MOWR, 1998). But the spatial and temporal variation of the water resource is erratic. Therefore it is a paradox that the world knows about Ethiopia by its recurring droughts linked with famine rather than by its vast natural resources. This impression is however largely due to media images.

4.Conclusions and Recomendations

As it has been discussed in the previous section rain-fed agriculture in the Arbaminch area is virtually impossible without supplementary irrigation. It can also be concluded that farmlands having the same climatic data could have different probabilities of dry-spells if their soil type and characteristics are different. This can be clearly observed from the results obtained for the maize & cotton crops for the two selected sites in the Arbaminch area. In fact, in several parts of Ethiopia, long-records of daily rainfall data may not be available. However, the methodology could be applied to those parts of the country that do have the data.

The result shows also, almost every year dry-spell duration that causes damage to crop yield occurs in the area. This will justify the failure of rain-fed agriculture in Ethiopia even though droughts (prolonged dry-spells) may not occur. Therefore the "Green Famine Dilemma" in Ethiopia is justified by the presented dry-spell analysis.

The dry-spell analysis presented in this paper has the following purposes:

It can be used for proper policy mak-

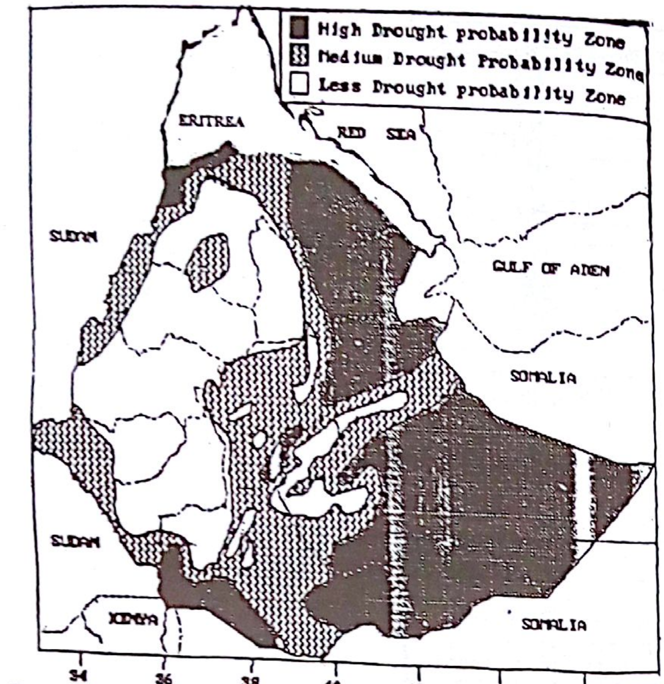

Figure 5. Drought Probability Map of Ethiopia (NMSA, 1996)

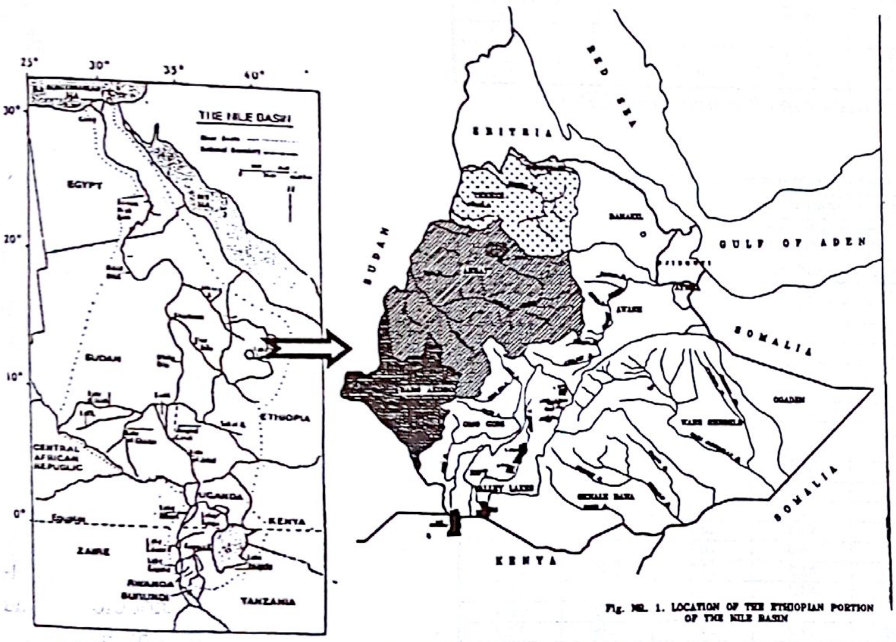

Figure 6. Location Map of the Nile River Basin (After Tefera, 1997)

Station Name = Arbaminch, Altitude = 1200m, Latitude = 6.05°N, Longitude = 38°E										
Month	Avg. rainfall (mm)	Temperature (°C)			Relative Humidity (%)			Avg. Daily Wind Speed		Sunshine Hours
		MAX.	MIN.	Avg.	MAX.*	MIN.*	Avg.**	(km/hr)	(m/sec)	
January	23	31.8	16.7	24.2	73	36	49	3.60	1.0	9.2
February	32	32.6	18.2	25.4	71	34	49	3.96	1.1	8.5
March	56	32.9	18.6	25.8	72	33	49	4.68	1.3	8.1
April	114	31.1	18.6	24.9	84	43	61	4.68	1.3	7.1
May	131	25.8	18.3	23.6	81	56	65	5.76	1.6	7.7
June	61	27.[illegible]	18.3	23.1	79	52	61	6.12	1.7	6.7
July	44	27.4	18.1	22.8	83	47	63	5.76	1.6	4.5
August	52	28.5	18.2	23.4	79	47	60	5.76	1.6	5.5
September	72	30.2	18.1	24.2	78	45	59	5.04	1.4	6.9
October	92	30.3	17.5	23.9	78	48	61	3.96	1.1	7.9
November	54	31.0	16.4	23.7	72	44	57	3.60	1.0	9.2
December	24	31.7	15.7	23.7	72	36	52	3.24	0.9	8.4
Total	753									

* = For the period 1973 - 1994 and ** = for the period 1987 - 1995 only!

Table 3. Meteorological data for Arbaminch (1973 - 1994)

ing in the prioritization of irrigation projects in the country;

It can be used to justify whether ranfed agriculture is sustainable or not in different parts of the country;

It can be used as a supporting tool for proper agricultural research and package development activities.

The majority of the country's 3.5 Mha irrigation potential (more than 60%) is located in the Ethiopian portion of the Nile River Basin (Fig. 6). Moreover, as can be seen from Fig. 5, the wettest part of the country is also found in the Ethiopian portion of the Nile River Basin. Therefore, Ethiopia will be forced to implement the small-scale, medium-scale and some of the large-scale irrigation projects identified in the various integrated watershed management studies of the Ethiopian portion of the Nile River Basin in order to avert the loss of lives of its citizens by frequently occurring famines. In this regard, sincere and sustainable consideration of the problem and full cooperation from the international community, the downstream riparian states of the Nile River Basin in particular, is essential.

Climate Station: Arbaminch			
Month	ET₀ (mm/day)	Rainfall (mm/month)	Effective Rainfall (mm/month)
January	4.5	28.6	27.3
February	4.8	31.1	29.6
March	5.2	58.5	53.1
April	4.7	134.3	105.4
May	4.6	155.4	116.8
June	4.3	66.0	59.0
July	3.8	47.6	44.0
August	4.3	55.6	50.6
September	4.6	74.6	65.7
October	4.5	100.8	84.6
November	4.5	53.6	49.0
December	4.2	23.6	22.7
Year Total	1642.3	829.6	707.6
Effective Rainfall with USBR method			

Table43. Potential evapotrnspiration obtained from CROPWAT

Crop Evapotranspiration and Irrigation Requirements								
Crop: Maize, Climate Station: Arbaminch, Planting date: 1 April								
Month	Decade	Stage	Coeff. K_C	ET_{CROP} mm/day	ET_{CROP} mm/decade	Eff. Rain mm/decade	IRR_{eq} mm/day	IRR_{eq} mm/decade
April	1	Initial	0.45	2.20	22.0	29.7	0.00	0.0
April	2	Initial	0.45	2.13	21.3	36.1	0.00	0.0
April	3	Develop.	0.55	2.57	25.7	37.1	0.00	0.0
May	1	Develop.	0.74	3.45	34.5	39.3	0.00	0.0
May	2	Develop.	0.94	4.32	43.2	40.9	0.23	2.3
May	3	Develop.	1.08	4.90	49.0	33.8	1.51	15.1
June	1	Develop/mid	1.13	5.01	50.1	25.4	2.47	24.7
June	2	Mid	1.13	4.90	49.0	17.7	3.14	31.4
June	3	Mid	1.13	4.71	47.1	16.7	3.05	30.5
July	1	Mid	1.13	4.44	44.4	15.7	2.88	28.8
July	2	Late	1.07	4.00	40.0	14.7	2.53	25.3
July	3	Late	0.96	3.73	37.3	15.4	2.19	21.9
August	1	Late	0.84	3.45	17.3	8.1	1.84	9.2
Total					480.9	330.5		189.2

Table 5 Crop Water requrements for maize crop obtained from CROPWAT

Table 6. Crop water requirements for cotton crop obtained from CROPWAT

Crop Evapotranspiration and Irrigation Requirements								
Crop: Cotton, Climate Station: Arbaminch, Planting date: 1 April								
Month	Decade	Stage	Coeff. K_C	ET_{CROP} mm/day	ET_{CROP} mm/decade	Eff. Rain mm/decade	IRR_{eq} mm/day	IRR_{eq} mm/decade
April	1	Initial	0.50	2.44	24.4	29.7	0.00	0.0
April	2	Initial	0.50	2.37	23.7	36.1	0.00	0.0
April	3	Initial	0.50	2.35	23.5	37.1	0.00	0.0
May	1	Develop.	0.56	2.58	25.8	39.3	0.00	0.0
May	2	Develop.	0.66	3.07	30.7	40.9	0.00	0.0
May	3	Develop.	0.78	3.51	35.1	33.8	0.12	1.2
June	1	Develop.	0.89	3.92	39.2	25.4	1.38	13.8
June	2	Develop.	0.99	4.32	43.2	17.7	2.55	25.5
June	3	Mid	1.05	4.38	43.8	16.7	2.71	27.1
July	1	Mid	1.05	4.13	41.3	15.7	2.56	25.6
July	2	Mid	1.05	3.92	39.2	14.7	2.45	24.5
July	3	Mid	1.05	4.10	41.0	15.4	2.56	25.6
August	1	Mid	1.05	4.32	43.2	16.1	2.70	27.0
August	2	Mid/late	1.04	4.40	44.0	16.9	2.72	27.2
August	3	Late	0.99	4.35	43.5	18.5	2.49	24.9
September	1	Late	0.94	4.22	42.2	20.2	2.19	21.9
September	2	Late	0.88	4.07	40.7	21.9	1.88	18.8
September	3	Late	0.83	3.79	37.9	24.0	1.39	13.9
Total					662.2	440.1		277.2

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