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Climatic Data and Rainfed Land Evaluation, the Case of Maichew, Northern Ethiopia

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Abstract Climate has a complex set of inter-related variables whereby a simple change in one variable or element could initiate a change on other elements. Climate change related risks lie at the very interface of different systems that has many variables which needs to be considered in a collective way. Agricultural activities like crop production, animal production, forestry and fishery can be considered altogether as a system under the umbrella of agriculture and climate also the other system. These two different systems are dependent on each other in one way or another where one system cannot be approached in an independent way in terms of development approach across locations as they are closely related to affect sustainable growth and development of nations. Scientific evidence shows that climate change is affecting agriculture in various ways. Nevertheless, as we develop the understanding of how for instance different crops respond to the climatic variable in a given environment could help to develop the resilience against the deleterious effects of climate change on the environment in general and humans in particular. This study is therefore aimed at characterizing climatic data for rainfed land evaluation in Maichew district, norther Ethiopia.

Keywords Climatic, Land Evaluation, Rainfed

1. Introduction

Rural communities are the primary prone people to the negative impacts of climatic variability on agricultural practices, the very weather dependent activity of humans (Hansen, 2002). In many cases, the vulnerability to climate change is high in the least developed countries as they are facing manifold forms of disaster like flood, drought, pest and diseases outbreaks, etc. The production of staple crops lies at the center of many Governmental policies and strategies and the maximization of crop yields has increasingly become among the primary priorities in the context of climate change effects and weather uncertainties (Sivakumar, 1988; Bazzaz and Sombroek 1996).

Increased knowledge and information sharing on the influences of climatic factors on agricultural production systems is an important task. Amidst of using improved technologies like irrigation, improved varieties, drought resistant varieties, etc., the impact of climatic variation is causing a huge impact in developing as well as developed countries. The sustained reliance of agriculture on climatic factors like water, temperature, light, etc., and the constant dependence of the world's major population on agricultural livelihoods along with the substantial and increased trends of climate change have all together created a crying need of a holistic and integrated approaches which can mitigate the impacts on agricultural productivity and production (Cynthia and Diana, 1992).

Apart from these, the complete dependence of many subsistence farmers on traditional agricultural systems, poor extension services and packages, weak access to improved agricultural technologies and others quadrupled the impact of climate on the wellbeing of many rural communities. As a result of this, the shift to improved and adaptive varieties, crop production management activities, the development of crops cycling criteria for the optimum use of water resources are some of the vital issues that needs to be considered by agricultural development stakeholders. This will also require a better understanding of the seasonal weather and climatic variabilities (Sivakumar *et al*., 2000).

2. Objectives

The aim of this study is to explore if and how improved understanding of the seasonal cycle of climate can be used for the benefit of local agricultural production in a typical area.

3. Methodology

Climatic data for two decades (1994 – 2015) was collected from the Meteorological Agency of Ethiopia. For the review

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of climate change and its impact on current agricultural production and productivity, different books, journals and lecture notes were reviewed. Apart from these, researcher's field level observations were also used as an input for the compilation of the article. For the analysis of the climatic data the equation developed by Gomez (1983) was utilized for the whole computation.

Climate, landscape, soil, and at times socio-economic data can be used as a basis for the comparison of productivity of different kinds of land, as well as for comparing and analysing the performance of different land uses on a specific location. The land evaluator can set the minimum data set and then analyse the suitability of the land for a selected crop variety with suitable crop cycle length by making use of the algorithm of Gommes (Ann and Eric, 2014). Then the computed result of the climatic data of Maichew district was compared with the specific climatic requirements of the C3, C4 and CAM plants which is summarized in box 1 and with some other literature reviews.

4. Results and Discussion

4.1. Site Description

Maichew is a district town located in the Southern Zone of Tigray Regional State of Ethiopia at 12°46'N latitude and an elevation of 1200 - 2478 meters above sea level. It is located at 665 km north of Addis Ababa, the capital of the country. According to Ethiopia's agro-ecological setting, Maichew and its surrounding environments are classified under the Weinadega (semi-temperate zone). The major livelihood of the community is coming from subsistence agriculture with an average size of 0.75 hectare cultivated land. Teff, barley, wheat, horse bean, sorghum, finger millet and chickpea are the major crops of the area (Shishay and Messay, 2014).

4.2. Climatic Variables

According to FAO (1993) climate 'constitutes a complex of inter-related variables. On average, through a set of regulatory mechanisms, a smooth change in one variable triggers smooth changes in most others. With the exception of possible qualitative and abrupt variations, such inter-relations are independent of atmospheric carbon dioxide (CO_2). The latter and other greenhouse gases play a part largely through their effect on the radiation balance of the atmosphere'.

There exists however, a weak linkage among cloudiness and wind while there is a strong correlation among, evaporation, temperature and rain which in turn demonstrates the probable escalation of the hydrological cycle (Figure 1).

NB. In the figure the solid and dotted lines indicate the positive and negative correlations, respectively. The strength of the correlation decreases from double heavy lines to thin single lines (FAO, 1995b).

Variability of climatic factors is likely to upsurge in absolute as well as relative terms under the global warming. These events are accompanied by thresholds that will impact the occurrence of many meteorological phenomena in various places. For example, cyclones of the tropics are 'fed' water vapor that evaporates from seas and oceans at a temperature of above 26 or 27°C. This indicates that, the higher average sea surface temperature will result higher frequency in the occurrence of tropical cyclones (Katz and Brown, 1992; McMahon et al., 2013). This kind of events will affect the services and products of oceans and water bodies.

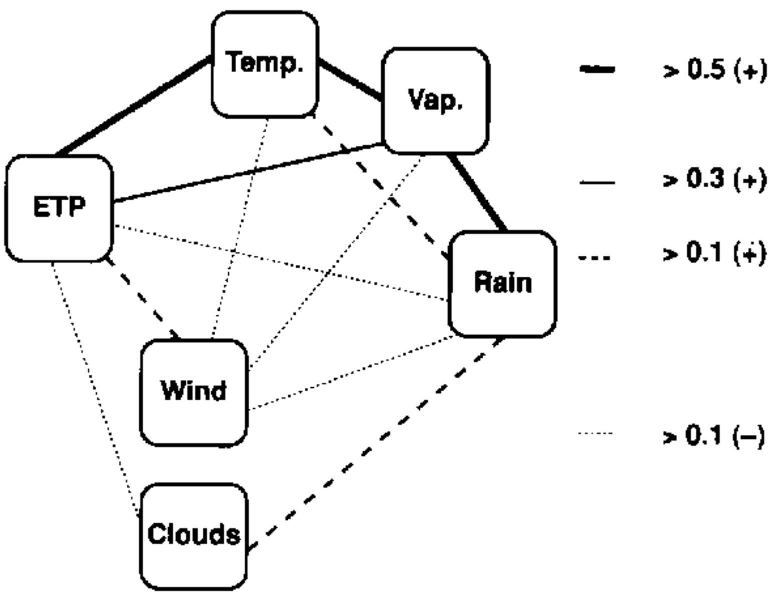

Figure 1. Some relationships among major climate variables (average temperature (*Temp.*); water vapour pressure (*Vap.*); rainfall (*Rain*); wind speed (*Wind*); cloudiness (*Clouds*); and evapo-transpiration potential (*ETP*) (FAO, 1995b)

Box 1.1. The major agricultural crops and the three photosynthetic pathways

Plants are classified as C_3, C_4 or CAM according to the products formed in the initial phases of photosynthesis.
C_3 species respond more to increased CO_2; C_4 species respond better than C_3 plants to higher temperature and their water-use efficiency increases more than for C_3 plants. There are some indications that enhancements can decline over time ('down-regulation').
C_3 plants: cotton, rice, wheat, barley, soybeans, sunflower, potatoes, most leguminous and woody plants, most horticultural crops and many weeds
C_4 plants: maize, sorghum, sugar cane, millets, halophytes (i.e., salt-tolerant plants) and many tall tropical grasses, pasture, forage and weed species
CAM plants (Crassulacean Acid Metabolism, an optional C_3 or C_4 pathway of photosynthesis, depending on conditions): cassava, pineapple, opuntia, onions, castor
(FAO, 1996)

Table 1. Climatic data of Maichew

Climatic Variables	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rain fall (mm)	21	12	45	70	61	29	183	234	76	56	30	23
Relative humidity (%)	70	65	66	64	61	51	66	74	63	63	64	63
Sun hours (Hrs)	8	8	8	8	8	6	6	5	7	7	7	9
Temp. max (°C)	20	22	22	24	25	26	23	22	23	21	20	20
Temp. min (°C)	7	8	10	11	12	14	13	13	11	9	7	7
Temp. ave (°C)	14	15	16	18	18	20	18	17	17	15	14	13
Evapotranspiration (mm)	43	46	57	59	60	48	41	38	43	50	45	42

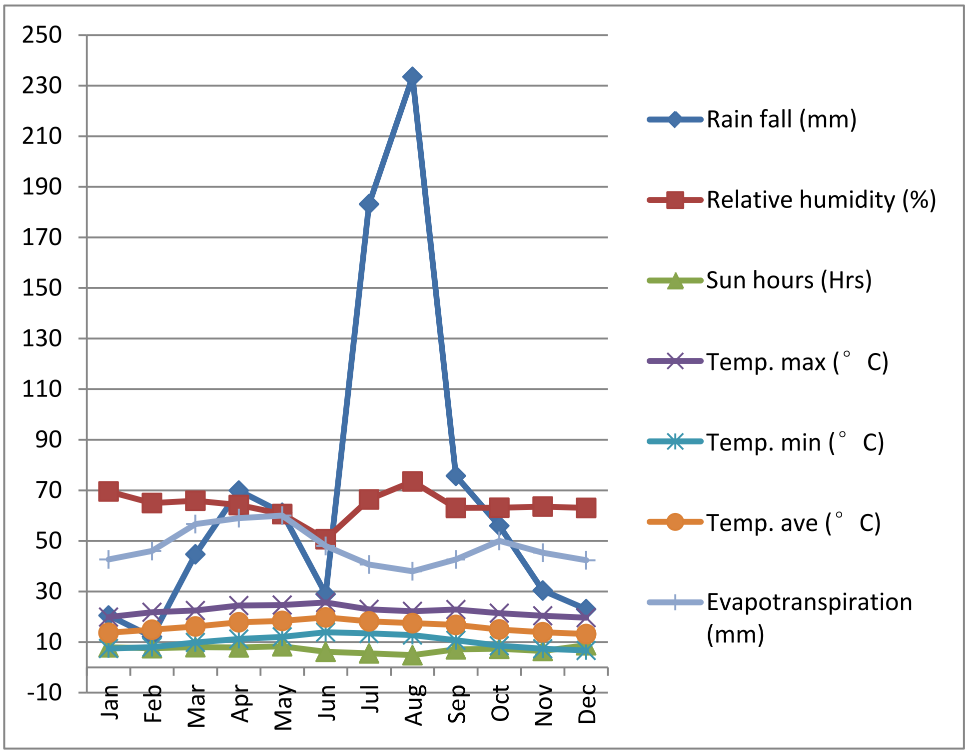

Figure 2. Graphical representation of the climatic data, Maichew

4.3. Characterization of Climatic Data for Maichew

The climatic data (1994 – 2015) which is composed of temperature, relative humidity, evapotranspiration, n-sunshine hours and rainfall was obtained from meteorological agency and is organized, averaged and tabulated in Table 1. From the data it is possible to articulate as the monthly precipitation distribution in Maichew is not uniform throughout the year; however, rainy periods frequently occur in both summer and winter, comparatively with no dry periods throughout the year, the rainfall being heavy in the summer months. The average temperature of the area ranges from 7-26°C.

In most cases published climatic data often refer to monthly periods. In the actual computation process however, decade data are required (10-day data). If not available it can also be interpolated from the monthly data. Climatic factors, when averaged over long time periods usually exhibit smooth curves when plotted against a specific period and hence the use of a decade is mandatory since it clearly reflects the average conditions (Ann and Eric, 2014).

By making use of the equation developed by Gommes (1983), the rainfall and evapotranspiration decade data was computed by the following formula and the output is presented in table 2 below:

$$D1 = ((5*M1) + (26*M2)-(4*M3))/81$$
$$D2 = (-M1 + (29*M2)-M3)/81$$
$$D3 = ((-4*M1) + (26*M2) + (5*M3)/81$$

Where: D1, D2, D3 are decades of the month under consideration

M1, M2, M3 are consecutive months

Information about the average daytime and nighttime temperatures is central subject since it helps to understand the behavior of given crop in general and in calculating the pattern of crop growth in particular. Rate of photosynthesis is determined by daytime temperatures whilst respiration takes place during day and night times.

To determine the Td and Tn the following equation of Petricevic cited by Gommes (1983) is used.

$$Td = (t\ max + t\ min/2) + (t\ max - t\ min/\pi)$$
$$Tn = (t\ max + t\ min/2) - (t\ max - t\ min/\pi)$$

Where: Td is day time and Tn is night time temperatures

$\pi=3.14$

⇒ January

$$Td = (20+7/2) + (20-7/3.14) = 17.64$$

$$Tn = (20+7/2) - (20-7/3.14) = 5.73$$

⇒ September

$$Td = (23+11/2) + (23-11/3.14) = 48$$

$$Tn = (24.9+9.2/2) - (24.6-9.2/3.14) = 9$$

4.4. Proposed Crops to be Grown in Maichew

Temperature is one of the main variables that govern the growth and development of crops. Corn (a C4 crop), for instance requires a minimum temperature of 10°C, an optimum minimum temperatures of 18°C and a maximum of 33°C. Other C4 crops like sorghum also have an absolute minimum temperature of 7 - 10°C, and an optimum maximum range of 33 to 40°C. Other C3 crops like wheat, soybean and alfalfa on the other hand have absolute minimum temperature that ranges 2 - 5°C and an optimum maximum of 23 - 33°C. In general, for cereal crops and for most of the C3 crops the minimum base temperature is 7°C. The photosynthetic rate of C4 plants like maize, in dry and hot weathers is two to three than C3 crops (e.g. Bluegrass). C4 crops can also perform well in areas of which are dominated by high rate of temperature and light intensity and limited amount of precipitation. On the other hand C3 crops are well adapted to cooler climates while CAM crops can adapt well in an arid environmental setting (Steven and James, 2011). Thus, these temperature thresholds can be used to evaluate the suitability of an area for a certain crop. The intensity, amount and timing of precipitation are also some of the critical element which can determine the suitability of an area for crops to be grown.

Table 2. Computed value for decade rainfall (RF) and evapotranspiration (ETo) from the monthly data

	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan
RF D1	3	12	22	22	4	49	83	36	21	12	8	8
RF D2	3	15	24	21	7	62	81	24	19	10	8	7
RF D3	6	18	24	18	18	72	71	16	16	8	7	6
RF total	**12**	**45**	**70**	**61**	**29**	**183**	**235**	**76**	**56**	**30**	**23**	**21**
ETo D1	15	18	19	21	17	14	13	14	16	15	14	14
ETo D2	15	19	20	20	16	14	13	14	17	15	14	14
ETo D3	16	20	20	19	15	13	13	15	17	15	14	15
ETo total	**46**	**57**	**59**	**60**	**48**	**41**	**39**	**43**	**50**	**45**	**42**	**43**

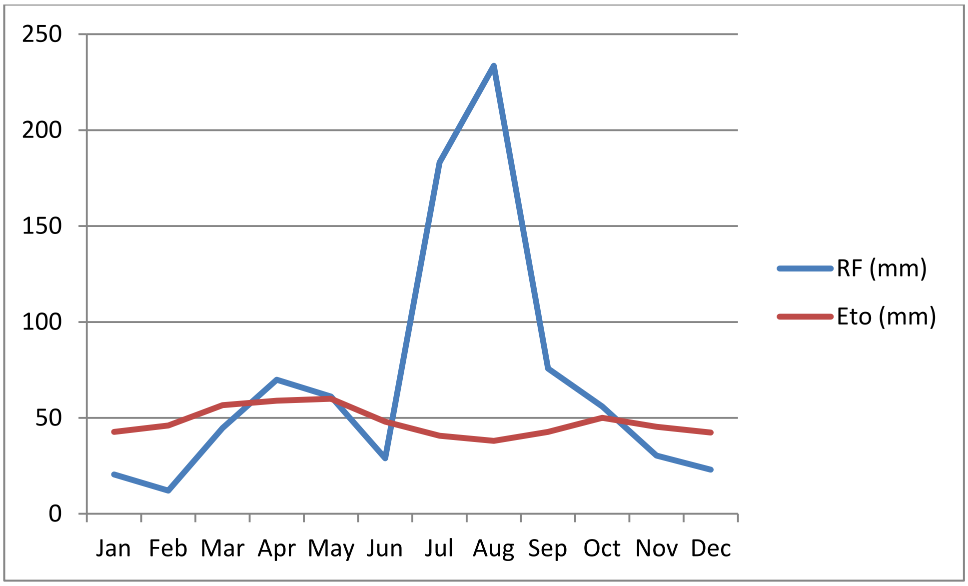

Figure 3. Graphical representation of rainfall and evapotranspiration data, Maichew

With the help of these explanation and box 1 the qualitative land suitability analysis for the different groups of crops (C3, C4 and CAM) was done for Maichew area by comparing the actual climatic requirements of the crops. The length of growing period of Maichew is also greater than 130 days (Figure 3) which can accommodate the growing period requirement of many crops.

Therefore, generally speaking based on the climatic data keeping other unknown factors like soil constant it is possible to say that Maichew is suitable to grow C3, C4 and CAM crop groups. In general the Maichew area is not unsuitable for any group; cognizant of the growing period of crops and climatic need considerations of crops (temperature, moisture availability, etc.). However, this proposed plan of production didn't consider socio economic issues of production, like customers' preference, market availability, inputs, etc.

In addition to this from the climatic data it is possible to have a look at there is a significant amount of precipitation which starts on January other than the main rainy season, though it didn't exceed the potential evapotranspiration, it indicates as there is a strong potential of using this rainfall for early preparation of seed bed and as well planting crops which didn't require high amount of water for their growth like chickpea, vetch, etc. Other than this with supplementary irrigation and by making use of early maturing verities it is also possible to produce crops during this period.

5. Conclusions

If planning of agricultural development is to be successful, improved estimates of probable climatic characteristics and timing are critical. Hence a comprehensive analysis of rainfall, temperature, relative humidity, and etc. data is a crucial component in the management of agricultural production. Based on the computation of the climatic data, it is possible to say as C3, C4 and CAM plants can be grown in the Maichew area.

Strategic crop production management is needed by analyzing the time series, start of rainy season and water balance of the long historical data for the prediction of a season to be wet or dry. Thus, this kind of information has to be used to assist farmers in selecting the appropriate crops that can best suit the agroecology of their localities. Special attention should also be given to evaluate the probabilities of extreme events (droughts, floods) and their effects on plant growth and yield.

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