STUDY OF AGRICULTURAL DROUGHT AND ITS IMPACT ON RICE YIELD IN RUPANDEHI DISTRICT, WEST NEPAL

Govinda Bhandari[a], Rijan Bhakta Kayastha[b]
[a,b] Department of Environmental Science and Engineering
Kathmandu University, Dhulikhel, Nepal.
[a]Corresponding author:govindabhandari84@yahoo.com

 ISSN 1923-6654 (print)
ISSN 1923-6662 (online). Available at http://www.ssrn.com/link/OIDA-Intl-Journal-Sustainable-Dev.html

Abstract: The relationship between climate (rainfall, temperature etc) and rice production was studied for the period 1975/76-2002/03 in Rupandehi District, Nepal. The monthly potential evapotranspiration (PET) value of rice is calculated by Blaney-Criddle equation. UNEP aridity index is used to identify the dryness of a region at rice growing seasons**.** The average Aridity Index (AI) of rice growing season from 1975 to 2002 is 1.54. The seasonal AI in 1979, 1991, 1992 and 1994 is 1.49, 1.19, 1.16 and 1.05 respectively i.e. below the average seasonal AI from 1975-2002. So, the rice yield in the year 1979, 1991, 1992 and 1994 has decreased due to the dryness of a region that is caused due to inadequate rainfall and gradual rise in temperature. Though modern facilities such as irrigation, improved seeds and fertilizers are available to some extent, weather and climate still plays an important role in the yield or rice in Nepal.

Keywords: agricultural drought, aridity index, potential evapotranspiration, Rupandehi district

I. INTRODUCTION

Nepal is a land locked country bounded on the north by China and on the south, east and west by India. The country is divided in to five north-south administrative development regions: Eastern, Central, Western, Mid western and Far western development region. Ecologically, the country is divided in to 3 belts namely; Mountain belt, Hill belt and Terai belt, running east to west with a non-uniform width from north to south (CBS, 2006).

Drought is a creeping phenomenon making an accurate prediction either of its onset or end is a difficult task (Wilhite and Glantz, 1985). Tannehill (1947) noted: "We have no good definition of drought". According to water balance concept, drought is a physical condition of the environment in which the amount of water available from precipitation and soil reservoir is insufficient to meet the evapotranspiration demand of crops, while for a meteorologist drought means a deviation from normal precipitation (Gupta and Duckstein, 1975; Dracup et al., 1980; Rogers and Armbruster, 1990; Paul, 1990; Bogardy et al., 1994). Drought is a sustained and regionally extensive but temporary occurrence of below average precipitation or naturally available water, in the form of river or stream run-off or ground water, caused by climatic fluctuations over an extended period (Noohi, 1988).

Generally, droughts are of three types: Meteorological, agricultural and hydrological droughts. According to Wilhite and Glantz (1985) four commonly used definitions of droughts are as follows:

The meteorological phenomenon of drought is a combination of atmospheric and soil moisture deficit resulting in setting off water balance in plants, animals, and under extreme conditions in man too (Gringof, 1983). Therefore, Meteorological drought is defined as a period when rainfall is significantly less than the long term average or some designed percentages, or less than some fixed value (Linsley et al., 1982; Downer et al., 1967).

Hydrological drought means below average values of: stream flow, contents in tanks and reservoirs, ground water; and soil moisture. Hydrological drought is the natural occurring phenomenon that exists when the precipitation has been significantly below the normal recorded levels causing a hydrological imbalance (Linsley et al., 1982).

Agricultural drought has been defined using the conditions of the crop, livestock, pasture and other agricultural systems. Agricultural drought will occur when water deficit severely affects the agricultural systems. Therefore, deficiency of rainfall has been the principal criteria for defining agricultural drought. Thus, agricultural drought is defined as "a deficit of rainfall with respect to the long-term mean, affecting a large area for one or several seasons or years that drastically reduce primary production in natural ecosystems and rain fed agriculture" (WMO, 1975).

Socioeconomic drought occurs when water supply is insufficient to meet water consumption for human activities such as agricultural activities, industry, urban supply, irrigation etc. (Heathcote, 1974; Gibbs, 1975).

Rice yield is quite variable from farm to farm and from country to country. Many factors such as fertility of the soil, farm management practices, variety, prevalence of diseases and insects, and the weather are responsible for this variation (Robertson, 1975).

The timely onset of monsoon is very important as the transplanting of rice seedling depends upon the arrival of monsoon rain. The preparation of rice nurseries starts almost a month ahead of transplanting. If the monsoon is delayed or weak in nature, the seedling can be damaged. During the time of transplantation, the top soil should be submerged, otherwise transplanting will not take place. Therefore, it is not only the onset of monsoon, the rainfall characteristics such as depth, frequency, intensity and distribution in time and space is all the important factors for the positive growth of rice (Nayava, 2008).

Water requirement of rice cultivation is greater than that of any crops of a similar duration. It varies with the type of soil, climatic condition, cultural practices and the duration of the variety grown. On an average, the amount of water required for rice is 500-650mm per month depending upon the prevailing conditions such as solar radiation, temperature, growth duration, variety, location etc. Generally, 4 to 5 mm of water per day is needed for evapotranspiration. Crops get wilting due to the insufficient amount of water. (Nayava, 2008). The optimum temperature for the better growth of rice and good yield is 22-30^{o}C. The maximum and the minimum temperature at which there is good growth of rice is 37^{o}C is 12^{o}C respectively. In general, irrigation is desirable whenever the soil moisture storage in the root zone drops to about 40 percent of capacity. In any case, to be effective, water must be applied before conditions reach the wilting point (Critchfield, 2006).

The production of rice at years 1976, 1977, 1979, 1981, 1982, 1986, 1991, 1992, 1994, 1998 and 2001 has been reduced significantly as in Table 2. During the period 1975-2002, there was a sharp decrease in the yield of rice in Rupandehi district in the years 1977, 1979, 1981, 1982, 1991 and 1992. A poor irrigation system has been observed in the respective years except in the years 1994 and 1997 as in Table 3. Taking in to consideration the importance of rainfall and temperature, this study attempts to identify the causes for the decrease of rice yield in Rupandehi district in the respective years.

II. Study Area

Rupandehi district, a part of Lumbini zone, is one of the seventy-five districts of Nepal. The importance of this district lies in that Lumbini is the birth place of Lord Buddha and a major pilgrimage centre for Buddhist. This district lies in the western terai region of the western development region of Nepal as in Figure 1. Its area is 1360 Km$^{2.}$ It is situated between 27^{0} 20' 00" to 27^{0} 47' 25" N latitude and 83^{0} 12' 16" to 83^{0} 38' 16" E longitude. The elevation ranges from 100-300 metres and the total population is about 7, 08,419 (CBS, 2001).

The maximum and minimum temperature recorded of this district is 47.7^{0}c and 8.75^{0}c respectively. The average annual rainfall is 1391 mm. Tinahau, Rohidi, Danab, Pahala, Kanchan, Kothi, Danda and Koilimai are the important rivers of this district (CBS, 2007). Administratively, the district is divided into 5 election area, 17 Illakas, 2 municipality and 69 Village Development Committee (VDCs) as in Figure 2.

III. Methodology

This research is based on the following methodology:

1. Analysis of rainfall and temperature data from 1975-2002 of Bhairahawa airport (Station no. 705)

The seasonal and monthly data of rainfall and temperature from 1975-2002 is analyzed and compared with the rice yield.

2. Estimation of Potential evapotranspiration (PET)

The Blaney-Criddle formula is used to calculate PET. Thus obtained PET value is used for the estimation of the Aridity Index (AI).

3. Aridity Index

UNEP aridity index (Hare, 1993) has been used in order to classify the aridity situation in the Rupandehi District.

4. Questionnaire Survey

A questionnaire survey in 21 VDCs and 1 municipality has been conducted to identify the possible causes for the decrease of rice yield.

IV. Data Analysis of Rice Growing Season (July-October)

Analysis of seasonal and monthly precipitation data

The average seasonal precipitation at a rice growing season from 1975 to 2002 is 1274mm. However, the precipitation in 1976, 1977, 1979, 1991, 1992, and

1994 is 1272mm, 1259mm, 1228, 974mm, 943mm and 860mm respectively i.e. below average seasonal precipitation and has contributed for the decrease in the rice yield. The amount of precipitation has been decreasing slightly in recent years as in Figure 3, which has decreased the rice yield.

The monthly average precipitation in July from 1975 to 2002 is 554mm. However, the precipitation in 1976, 1991, 1992, and 1994 is 439mm, 215mm, 350mm, and 246mm i.e. below monthly average precipitation and has caused water scarcity at the period of rice plantation. The average precipitation in August from 1975 to 2002 is 385mm. However, the precipitation in 1979, 1992, 1994 is 293mm, 270mm, 336mm i.e. below monthly average precipitation and has caused water scarcity at the period of rice maturity. Similarly, the average precipitation in September from 1975 to 2002 is 268mm. However, the precipitation in 1977, 1979, 1992 is 64mm, 107mm, 163mm i.e. monthly average precipitation as in Figure 4, and has caused water scarcity at the period of rice maturity. The average precipitation in October from 1975 to 2002 is 67mm. However, the precipitation in 1992 is maximum i.e. 160mm. This huge amount of water has caused the water logging in the agricultural plots. So, the low precipitation in the plantation period in different months of the years 1976, 1977, 1979, 1991, 1992, 1994 has contributed for the decrease in the rice yield.

Analysis of seasonal and monthly temperature data

The average seasonal temperature at a rice growing season from 1975 to 2002 is 28.37^{o}C. The seasonal temperature in 1979, 1991 and 1994 is 28.60^{o}C, 28.45^{o}C and 28.38^{o}C respectively i.e. above the average seasonal temperature. The monthly average temperature of July from 1975-2002 is 29.29^{o}C whereas the temperature of July in 1979, 1991 and 1994 is 29.60^{o}C, 29.80^{o}C and 30.10^{o}C respectively i.e. above the monthly average temperature as in Figure 5. The average temperature of August from 1975-2002 is 29.46^{o}C whereas the temperature of August in 1979 and 1994 is 30^{o}C i.e. above the monthly average temperature. The average temperature of September from 1975-2002 is 28.71^{o}C whereas the temperature of September in 1979 and 1991 is 29^{o}C and 28.90^{o}C respectively i.e. above the monthly average temperature. The average temperature of October from 1975-2002 is 26.19^{o}C whereas the temperature of October in 1979 is 26.20^{o}C i.e. above the monthly average temperature. Therefore, a gradual increase of temperature in different months of rice growing seasons in the years 1979, 1991 and 1994 has been observed (Figure a,b,c,d).

V. Estimation and Analysis of Potential Evapotranspiration

Potential evapotranspiration (PET) means the rate of evapotranspiration from a fully vegetated watershed when sufficient moisture is always available to completely meet the requirements (Patra, 2002).

PET is calculated by the Blaney-Criddle formula as

$PET = 2.54\, K\, F$ and $F = \sum P_h\, T_f / 100$,

where,

K = an empirical coefficient, depends on the type of the crop; value of K for Rice is 1.10 (Subramanya, 2007)

P_h = monthly percent of annual day time hours, depends on the latitude of the place as in Table 1

T_f = mean monthly temperature in ^{o}F

F= sum of monthly consumptive use factors for the period

The average seasonal PET at a rice growing season from 1975 to 2002 is 814.42mm. However, the PET in 1979, 1991, 1994 is 822.78mm, 820.21mm, 819.53mm respectively i.e. above the average seasonal PET. The monthly average PET of July from 1975 to 2002 is 228.8mm. However, the PET of July in 1979, 1991, and 1994 is 230.41mm, 231.38mm and 232.84mm respectively i.e. above the monthly average PET value as in Figure 7a. The average PET of August from 1975 to 2002 is 218.75mm. However, the PET of August in 1979 and 1994 is 219.69mm and 220.15mm respectively i.e. above the monthly average PET as in Figure 7b. The average PET of September from 1975 to 2002 is 190.14mm. However, the PET of September in 1979, 1991, and 1994 is 195.97mm, 195.55mm and 193.03mm respectively i.e. above the monthly average PET as in Figure 7c. The average PET of October from 1975 to 2002 is 176.50mm. However, the PET of October in 1979 is 176.72mm i.e. above monthly average PET as in Figure 7d. Therefore, the high PET in different months of 1979, 1991 and 1994 has decreased the yield of rice.

VI. Analysis of Aridity Index (AI)

AI represents the severity of dryness of a region. Aridity is defined as the more or less repetitive climatic condition, which is characterized by a lack of water (Perry, 1986). It should be noted that aridity can be considered on seasonal or monthly basis (Coughlan, 2003). Since rainfall is the main source of water over land, it is taken to be the most indicative parameter of water shortage. Many aridity indices have designed to delimit climate and vegetation of a location. In this study, UNEP aridity index is used as follows:

Aridity Index (AI), AI=P/PET

where,

P=Precipitation in mm and PET=Potential evapotranspiration in mm.

The average AI of rice growing season from 1975 to 2002 is 1.54. However, the AI in 1979, 1991, 1992 and 1994 is 1.49, 1.19, 1.16 and 1.05 respectively i.e. below the average AI of rice growing season as in Figure 8. The average AI of July from 1975 -2002 is 2.6 whereas the AI of July in 1991, 1992 and 1994 is 0.93, 1.54 and 1.06 respectively i.e. below the average. The average AI of August from 1975 -2002 is 1.89 whereas the AI of August in 1979, 1992 and 1994 is 1.33, 1.25 and 1.53 respectively i.e. below the average. The average AI of September from 1975 - 2002 is 1.14 whereas the AI of July in 1979 and 1992 is 0.55 and 0.84 respectively i.e. below the average. So, the rice yield in the years 1979, 1991, 1992 and 1994 has decreased due to the dryness of a region that is shown by the lower value of seasonal and monthly AI in different years.

VII. QUESTIONNAIRE SURVEY

170 farmers are selected randomly from 21 VDCs and 1 municipility for the questionnaire survey. Among them, 121 farmers are selected from Aama, Suryapura, Madhubani, Bisnupura, Anandaban, Butwal, Shankarnagar, Gongolia, Khadabangai, Motipur, Semlar, Siktaham, Tikuligad, Sadi VDCs and 49 farmers are selected from Ekala, Madhawaliya, Karahaiya, Makrahar, Masina, Soura Pharsatikat, Gagedi, Amuwa VDCs. A sample of questionnaire that has been used in the survey includes the information on the following topics. Structured questions related to the topics were asked at the time of survey.

a. Identifying household
b. Informants background
c. Family size
d. Information about land
e. Agricultural information
f. Information on Natural disaster

VIII. RESULTS AND DISCUSSION

The low precipitation and high PET in the rice plantation period in different months of the years 1976, 1977, 1979, 1991, 1992, 1994 has been observed. So, the rice yield in the years 1979, 1991, 1992 and 1994 has decreased due to the dryness of a region that is shown by the lower value of seasonal and monthly AI in different years.

121 farmers from Aama, Suryapura, Madhubani, Bisnupura, Anandaban, Butwal, Shankarnagar, Gongolia, Khadabangai, Motipur, Semlar, Siktaham, Tikuligad, Sadi VDCs have a good yield of rice. Farmers in these areas have good farming techniques and independent. Agricultural facilities like irrigation, manure, tools, human resource etc are found abundantly in these VDCs. The soil is black and less number of weeds and insects are observed in this region. So, the yield of rice is good.

49 farmers from Ekala, Madhawaliya, Karahaiya, Makrahar, Masina, Soura Pharsatikat, Gagedi, Amuwa VDCs have a poor production of rice. Farmers in these areas have poor knowledge of farming techniques and are independent. Agricultural facilities like irrigation, manure, tools, human resource etc are scarce in these VDCs. The soil is brown and greater number of weeds and insects are observed in this region. So, the yield of rice is poor.

The area of Rupandehi district irrigated in 1991, 1992 and 1994 is 1388 ha, 200 ha and 3865 ha respectively. However, in 1997 the irrigated area is 5309ha. Therefore, the poor irrigation in the years 1991, 1992 and 1994 has contributed for the decrease of rice yield in Rupandehi district.

IX . CONCLUSION

For the last 27 years from 1975 to 2002 except in 1989 the analysis, shows that the rice yield was badly affected in four years, particularly, in the years 1976, 1981, 1992 and 2001. This study of agricultural drought in Rupandehi district in 1976, 1977, 1979, 1991,1992 and 1994 shows that the inadequate rainfall and gradual increase in temperature has caused the reduction of rice production. During those years, the amount of rainfall was found to be extremely low and is not sufficient for the growth of rice. Especially, in different months of 1979, 1991 and 1994 the amount rainfall is very less and, there a gradual temperature rise has been observed which has significantly contributed for the increase of PET. The AI in different months of 1979, 1991 and 1994 is less then the average value of AI from 1975-2002 and has caused the decrease of rice yield. Therefore, the severe agricultural drought in Rupandehi district is observed in the years 1979, 1991 and 1994.

ACKNOWLEDGEMENT

The authors would like to dedicate this research report to Department of Hydrology and Meteorology, Central Bureau of Statistics and Ministry of Agriculture and Cooperatives for providing the necessary data. The author wishes to thank Mr. Deepak Koirala, Mrs. Maya Pandey, Mr. Chudamani Pandey and Mr. Bikram Shrestha for their cooperation during the survey.

REFERENCES

[1] Bogardy, I., Matyasovszky, I., Bardossy, A. and Duckstein, L. 1994. A hydroclimatological

model of areal drought. J. Hydrology 153: 245-264.

[2] CBS (Central Bureau of Statistics).2006. Nepal in figures. Central Bureau of Statistics. National Planning Commission Secretariat, Kathmandu, Nepal, pp 12.

[3] CBS (Central Bureau of Statistics). 2007. District profile of Rupandehi. Central Bureau of Statistics. National Planning Commission Secretariat, Kapilbastu, Nepal, pp 104.

[4] Coughlan, M.J. 2003. Defining drought: a meteorological viewpoint. Science for Drought. In: Proc. of the National Drought Forum. Brisbane, Australia, pp 24-27.

[5] Critchfield, Howard J. 2006. General Climatology, Prentice Hall of India Private Limited, New Delhi, India, pp 453.

[6] Downer, R.N., Siddiqui, M.M. and Yevjevich, V. 1967. Applications of the runs to hydrologic drought. In Proc. International Hydrology Symposium Colorado State University, Fort Collins. pp 496-505.

[7] Dracup, J. A., Lee, K.S. and Paulson, Jr. E.G. 1980. On the definition of droughts, Water Resources Research, 16 (2): 297-302.

[8] Gibbs, W.J. 1975. Drought-Its definition, delineation and effects. Special Environment Report No. 5. Geneva, Switzerland. pp 186.

[9] Gringof, I.G. 1983. Meteorological Aspects of Desertification (CAgM Report No. 18), WMO, Geneva: 1-20.

[10] Gupta, V.K. & Duckstein, L. 1975. A Stochastic analysis of extreme droughts, Water Resources Research, 11 (2): 221-228.

[11] Hare, F.K. 1993. Climate variation, drought and desertification. WMO, Geneva, Switzerland pp 44.

[12] Heathcote, R.L. 1974. Drought in South Australia. In: G.F. White (ed) Natural Hazards: Local, National, Global. Oxford, New York. pp 129.

[13] Linsley, R.K., Kohler, M.A. and Paulhus, J.L.H. 1982. Hydrology for Engineers. McGraw Hill, New York. pp 508.

[14] MoAC 2005. Statistical Information on Nepalese Agriculture. Ministry of Agriculture and Cooperatives, Kathmandu, Nepal: 1-34.

[15] Noohi, K. 1988. Agricultural Meteorology (CAgM Report No. 32), WMO, Geneva: 1-5.

[16] Patra, K.C. 2002. Hydrology and Water Resources Engineering. Narosa Publishing House, New Delhi, India, pp 561.

[17] Paul, D.K. 1990. Prediction of drought occurrence at Hazaribagh, J. Ind. Science., Congr. Asso., 25 (1): 22-24.

[18] Perry, A.H. 1986. Precipitation and climate change in central Sudan. In: H.R.J. Davies (ed) Rural Development in the White Nile Province, Sudan. A Study of Interaction between Man and Natural Resources. The United Nations University, Tokyo. pp 33-42.

[19] Robertson, G.W. 1975. Rice and Weather (Technical Note No. 144), WMO, Geneva: 1-29.

[20] Rogers, J.D. & Armbruster, J.T. 1990. Low Flows and hydrologic droughts. Surface Water Hydrology, Geo. Society of America, Boulder, CO, pp.121-130.

[21] SOHAM (Society of Hydrologists and Meteorologists) –Nepal. 2008. Journal of Hydrology and Meteorology, Kathmandu, Nepal: 93-102.

[22] Subramanya, K. 2007. Engineering Hydrology, Tata McGraw Publishing Company Limited, New Delhi, India, pp 387.

[23] Tannehill, I.R. 1947. Drought: Its Causes and Effects. University Press, Princeton. pp 264.

[24] Tiwari, K.N. et al. 2007. Characterization of meteorological drought, Hydrology Journal, 30 (1-2) March-June: 15-27.

[25] Wilhite, D.A. and Glantz, M.H. 1985. Understanding the drought phenomenon: The role of definitions. Water International 10 (3):111-120.

[26] WMO (World Meteorological Organization). 1975. Drought and Agriculture. WMO. Technical Note 138, WMO, Geneva, Switzerland. pp 127.

Figures:

Figure 1: Map of Nepal and location of Rupandehi district

Figure 2: 21 VDCs on 1 municipality surveyed in Rupandehi (dark shaded areas)

Figure 3: Trend of seasonal precipitation of the rice growing season

Figure 4: Monthly precipitation of the rice growing season

Figure 5: Trend of seasonal temperature of the rice growing season

Figure 6: Monthly mean temperature (1975-2002) in mm in Rupandehi

6a: Monthly mean temperature of July

6b: Monthly mean temperature of August

6c: Monthly mean temperature of September

6d: Monthly mean temperature of October

Figure 7: Monthly Potential evapotranspiration (PET) and Precipitation (PPT) in mm

7a: Monthly mean PET and PPT of July

7b: Monthly mean PET and PPT of August

7c: Monthly mean PET and PPT of September

7d: Monthly mean PET and PPT of October

Figure 8: Seasonal Aridity Index (AI) of Rupandehi

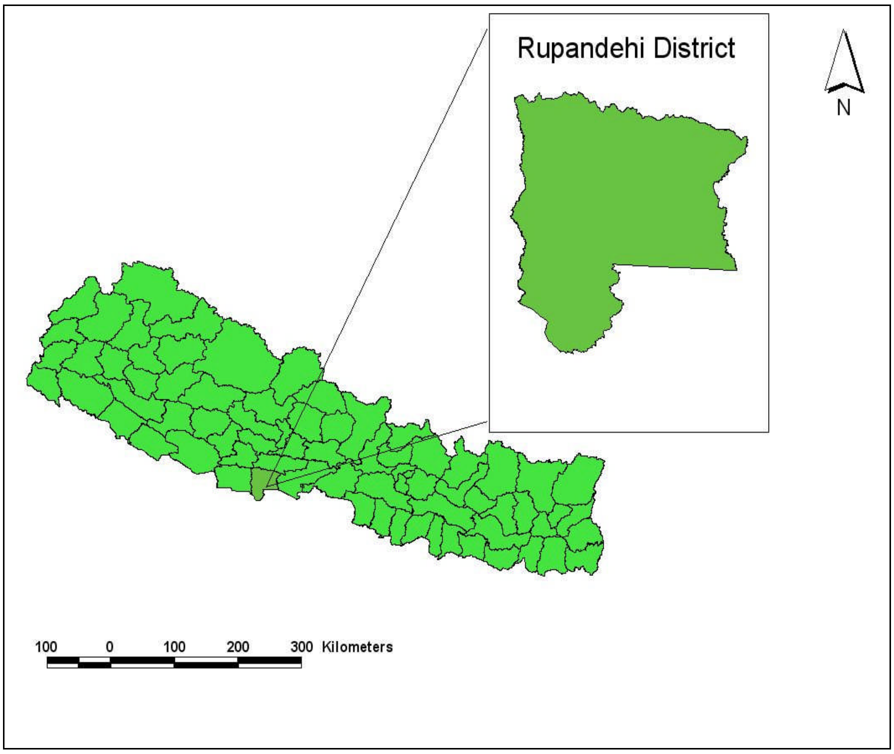

Figure 1

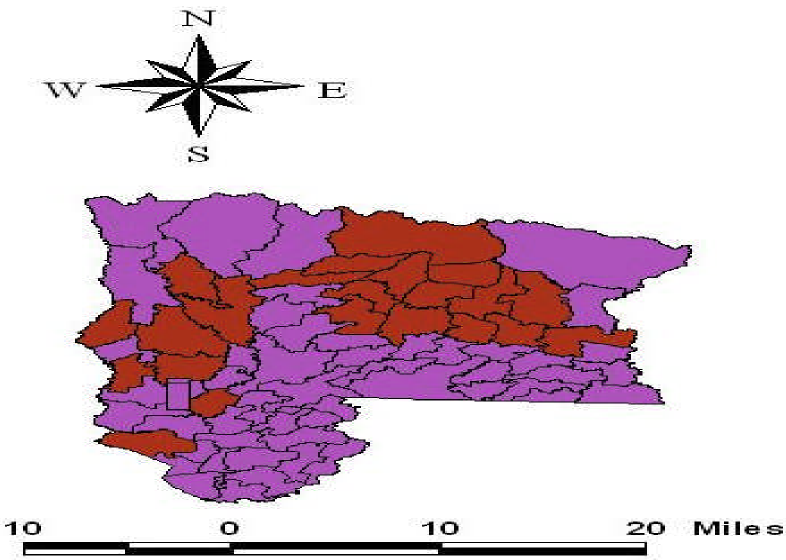

Figure 2

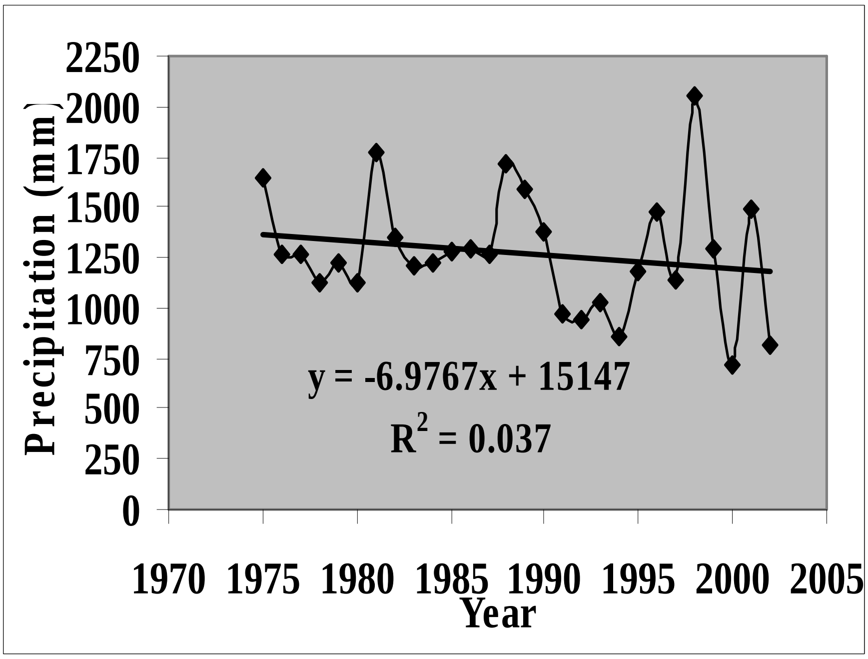

Figure 3

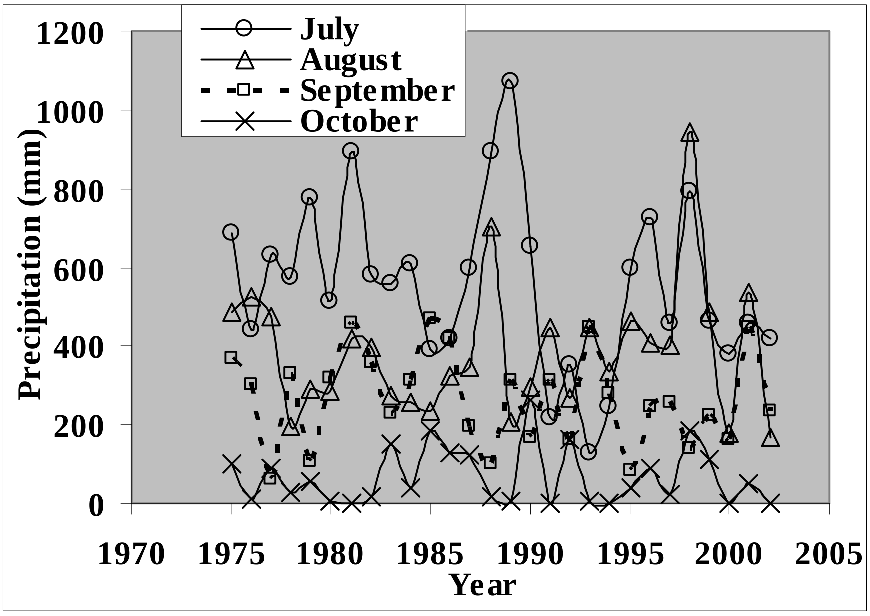

Figure 4

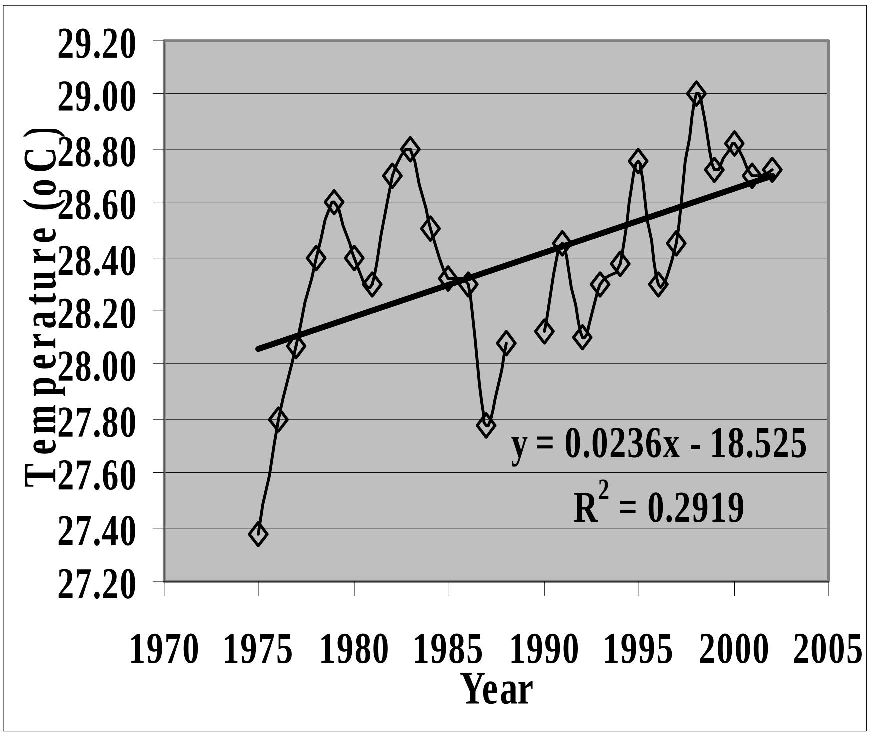

Figure 5

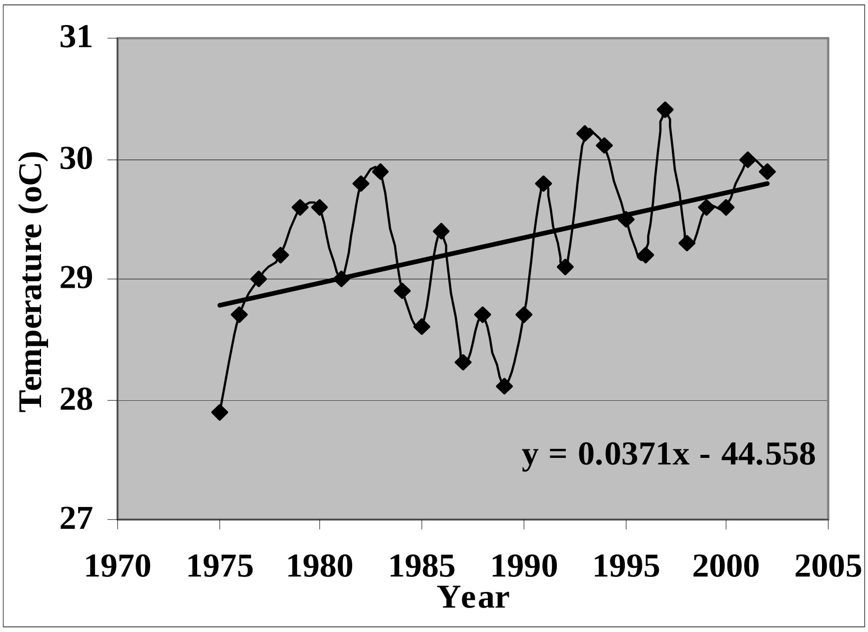

Figure 6 (a)

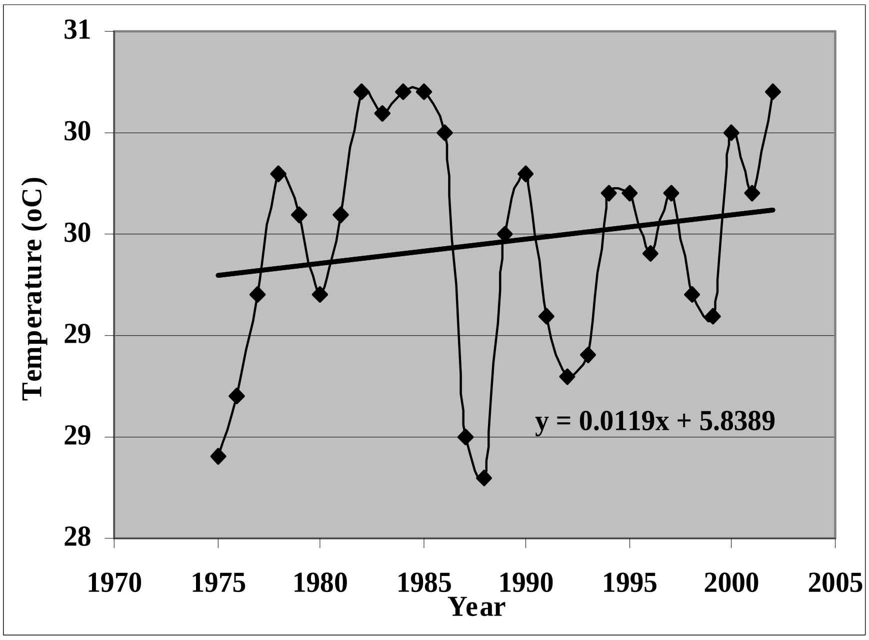

Figure 6 (b)

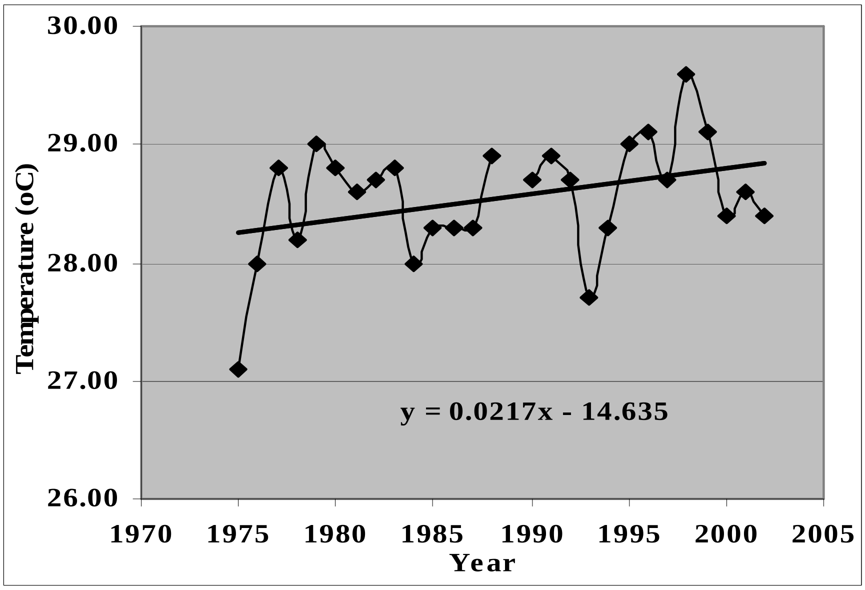

Figure 6 (c)

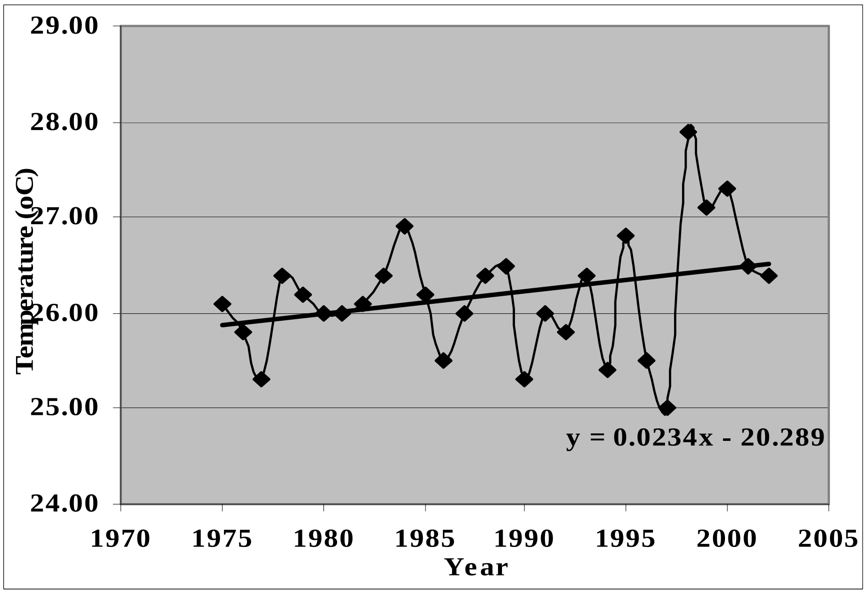

Figure 6 (d)

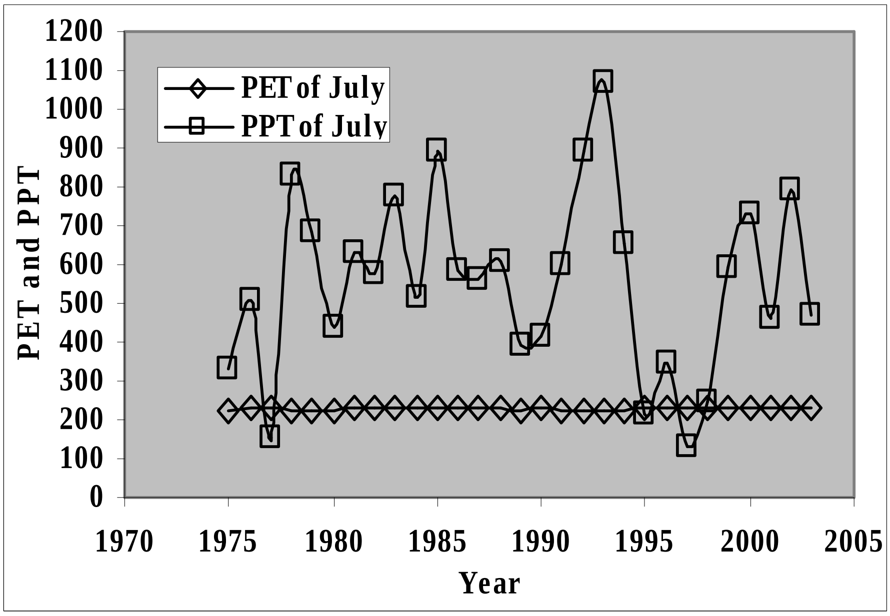

Figure 7a

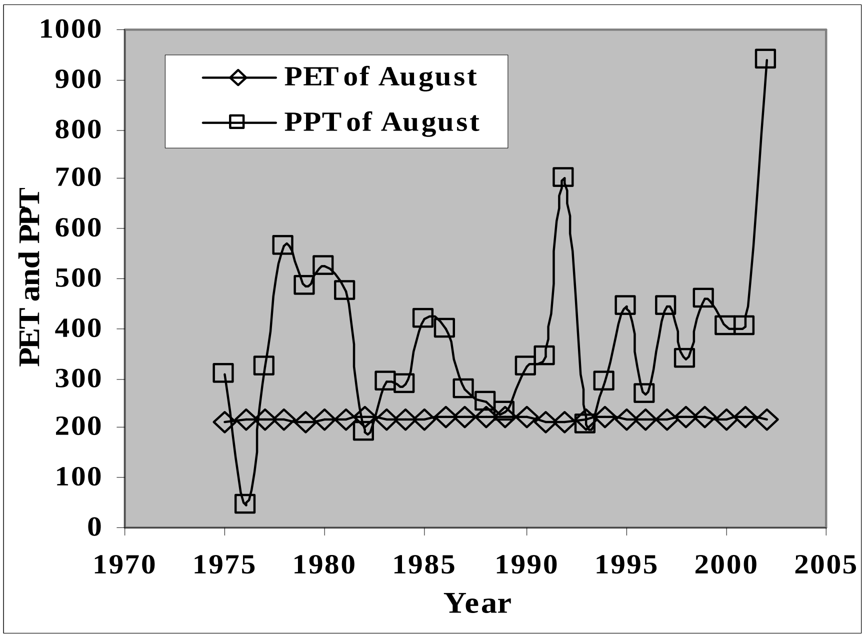

Figure 7b

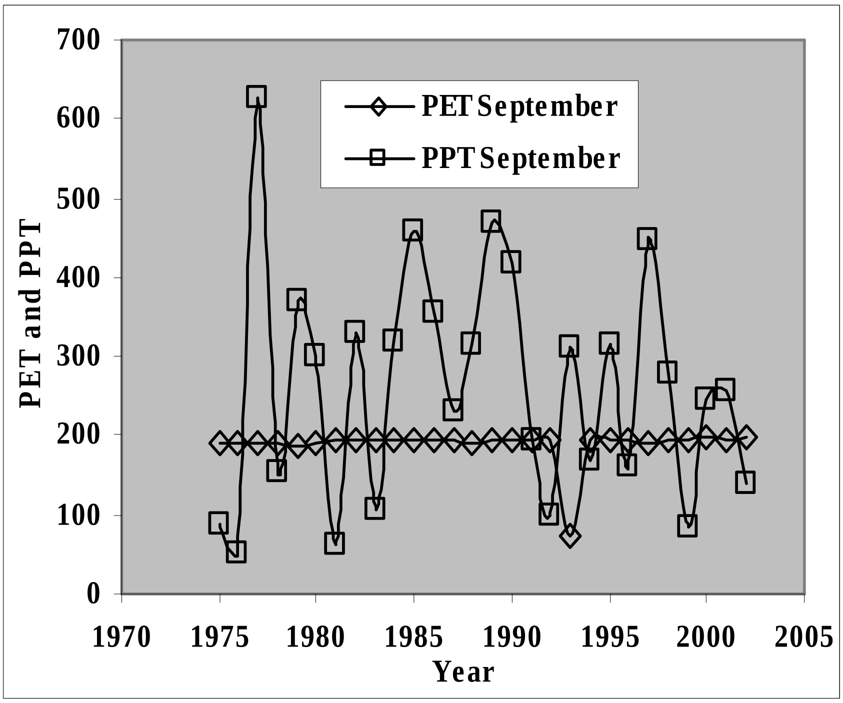

Figure 7c

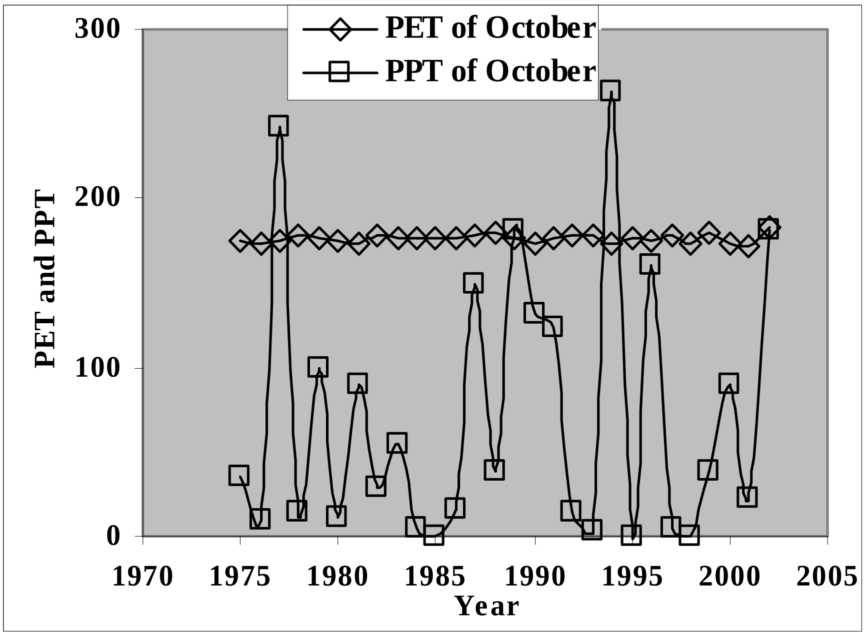

Figure 7d

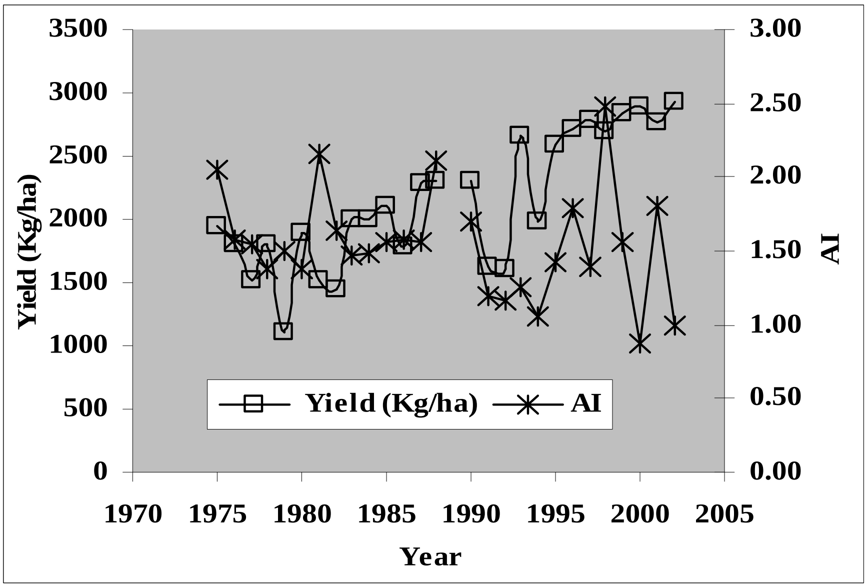

Figure 8

Tables:

Table 1: Value of P_h

Table 2: Yield of rice (Kg/Ha) from 1975-2002 in Rupandehi District

Table 3: Average Coverage by irrigation sources in Rupandehi district (Ha)

Latitude	**July**	**August**	**September**	**October**
30^oN	9.67	9.22	8.33	7.99

Table 1

Years	**Yield (Kg/ha)**	**Years**	**Yield (Kg/ha)**
1975/76	1941	1989/90	NA
1976/77	1810	1990/91	2300
1977/78	1514	1991/92	1633
1978/79	1800	1992/93	1600
1979/80	1105	1993/94	2656
1980/81	1900	1994/95	1984
1981/82	1520	1995/96	2581
1982/83	1442	1996/97	2707
1983/84	2000	1997/98	2779
1984/85	2000	1998/99	2700
1985/86	2100	1999/00	2832
1986/87	1792	2000/01	2886
1987/88	2292	2001/02	2769
1988/89	2301	2002/03	2926

Table 2 Source: (MoAC, 2005)

Years	**Irrigated land (Ha)**	**Years**	**Irrigated land (Ha)**
1990/91	26973	1997/98	5309
1991/92	1388	1998/99	235
1992/93	200	1999/00	NA
1993/94	NA	2000/01	450
1994/95	3865	2001/02	570
1995/96	NA	2002/03	220
1996/97	866	2003/04	800

NA=Not Available Source: Department of Irrigation

Table 3