Online ISSN: 2249-4626
Print ISSN: 0975-5896

Global Journal

of Science Frontier Research: D

Agriculture and Veterinary

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VOLUME 13 ISSUE 5 VERSION 1.0

Global Journal of Science Frontier Research: D
Agriculture & Veterinary

Global Journal of Science Frontier Research: D
Agriculture & Veterinary
Volume 13 Issue 5 (Ver. 1.0)

Open Association of Research Society

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Offset Typesetting

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Contents of the Volume

Global Journal of Science Frontier Research
Agriculture and Veterinary
Volume 13 Issue 5 Version 1.0 Year 2013
Type : Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 2249-4626 & Print ISSN: 0975-5896

Requirement Based Evaluation of Energy Consumption in Agricultural Sector - A Case Study

By K. Swarnasri & Dr. SVL Narasimham
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Abstract - Agriculture is primary occupation in India and largely depends on ground water because of unscheduled canals, lowrain fall etc., Electrical Energy consumption for agricultural purpose has a major share in national energy consumption. Even though several methods have been followed from the past to lift ground water, pumps operated by electrical motors occupy larger percentage. Thus availability of electricity and availability of ground water became two vital elements for flourishment of agriculture and country to prosper. Operating hours of pumpset for various crops depends on amount of water required for the crop. In a crop cycle, for proper crop growth several irrigation cycles need to be scheduled. As there is direct dependence on electricity with water required for crops, estimation of energy consumed based on water required will definitely be an imperative task of interest. There is always a chance to show a high value for energy consumed by agricultural sector, which is not metered in Andhra Pradesh. In this paper, energy consumed for various crops is estimated in six districts of Andhra Pradesh covered by Andhra Pradesh Southern Power Distribution Company Limited (APSPDCL). This method may be useful in arriving at most reliable estimates for the energy consumed in agriculture.

Keywords : *agricultural sector, crop water requirement, electrical energy consumption.*

GJSFR-D Classification : *FOR Code: 070199*

REQUIREMENT BASED EVALUATION OF ENERGY CONSUMPTION IN AGRICULTURAL SECTOR A CASE STUDY

Requirement Based Evaluation of Energy Consumption in Agricultural Sector – A Case Study

K. Swarnasri [α] & Dr. SVL Narasimham [σ]

Abstract - Agriculture is primary occupation in India and largely depends on ground water because of unscheduled canals, lowrain fall etc., Electrical Energy consumption for agricultural purpose has a major share in national energy consumption. Even though several methods have been followed from the past to lift ground water, pumps operated by electrical motors occupy larger percentage. Thus availability of electricity and availability of ground water became two vital elements for flourishment of agriculture and country to prosper. Operating hours of pumpset for various crops depends on amount of water required for the crop. In a crop cycle, for proper crop growth several irrigation cycles need to be scheduled. As there is direct dependence on electricity with water required for crops, estimation of energy consumed based on water required will definitely be an imperative task of interest. There is always a chance to show a high value for energy consumed by agricultural sector, which is not metered in Andhra Pradesh. In this paper, energy consumed for various crops is estimated in six districts of Andhra Pradesh covered by Andhra Pradesh Southern Power Distribution Company Limited (APSPDCL). This method may be useful in arriving at most reliable estimates for the energy consumed in agriculture.

Keywords : agricultural sector, crop water requirement, electrical energy consumption.

I. Introduction

Over the past two decades, ground water has emerged as one of the primary source for irrigation. Free access to power and availability of water at point of use and whenever required are leading the farmers to adapt ground water irrigation over large scale. Supply of power to agriculture has become an important and inevitable aspect.

During the past four decades, percentage of land irrigated through surface irrigation has declined and subsequently millions of small, private bore wells have come into use resulting in increased use of ground water resources and increased energy consumption. In many Indian states the consumption of 35-45% of total energy is reported in this sector and it represented not more than5-10% of state electricity board's revenue [1]. Increase in number of bore wells has put a tremendous stress on power distribution system. Though there has been an increase in number of wells, after a certain break point extraction of ground water and area irrigated with groundwater has stabilized. In Andhra Pradesh ultimate irrigation potential through ground water is 32 Million Hectares[2].

Linkage between energy and irrigation are reviewed by many authors with Government, Non-Government and social organizations in different perspectives with the aims of reduction in ground water draft, ultimate ground water potentialcomputations, water and energy nexus etc.,. S. Padmanabhan& Ashok Sarkar addressed the benefits and importance of Demand side management in India with emphasis on agricultural sector [1]. The linkage between energy consumption and agricultural ground water draft for many years with insights of India and Mexico are reviewed in [3].

Present tariff structure, poorenergy and water management appear to be responsible for high energy loss associated with the distribution network, end use of electricity in irrigation water pumping and water loss.

A careful examination of higher losses reveals that a poor cycle that exists with the involvement of two subsystems operating in tandem with one another - the electrical distribution system and the water pumping system are responsible. Because of this poor cycle, returns from this sector are very minute compared to huge investments and the utility revenues are deteriorating and subsequently fewer revenues are available for rehabilitation of distribution systems. This resulted in suboptimal planning, low quality of works and further forcing the utility to consider load shedding. Table – I describes the total energy sales and revenue from agricultural sector for various years. Table – II shows the number of pump sets used for irrigation under Category V and gross area irrigated across the state.

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Table I : Amount of power supplied and revenues in Andhra Pradesh

Year →	2008-09	2009-10	2010-11	2011-12
Total Energy sales for all DISCOMs (MU)	52,527.59	57,201.70	65037.84	70422.30
Energy Sales under category V (MU)	13,397.80	14,203.66	15197.39	16565.16
Total Revenues from tariffs (Crores)	13,510.00	15,374.33	20,939.00	25,957.91
Revenue under Category V (Crores)	142.00	129.74	74.51	147.78

Source : APTRANSCO

Table II : Number of pump sets energized and gross area irrigated

Year	No. of pumpsets energized	Gross area irrigated by Wells (Mha)	Year	No. of pumpsets energized	Gross area irrigated by Wells (Mha)
2000	19,18,712	26.93	2006	24,40,823	28.91
2001	19,24,543	26.18	2007	25,27,800	31.74
2002	19,34,389	24.78	2008	25,99,635	34.71
2003	22,49,894	25.73	2009	26,80,671	33.43
2004	23,09,605	25.63	2010	27,69,275	36.72
2005	23,74,365	27.96	2011	29,09,006	36.99#

Source: Agricultural research data book – 2009 & Directorate of Economics and Statistics

Estimated from previous years data

The capacity of pump sets that are energized is based on the region where it is installed, crops irrigated, area of land holding. Water pumped from each pumpset is based on type of crop, depth of irrigation required, type of soil, atmospheric conditions, percolation, irrigation schedules etc. energy consumption by each pumpset is having a direct relation with amount of water pumped assuming that the water is abundantly available.Over exploitation of ground water in many regions of the state combined with idle operation of pumpsets is further leaving the entire distribution network as low efficient system.

II. Water Requirement for Crops

Regardless of the sources, water requirement (WR) of a crop is the quantity of water required in a given crop period for its maturity. WR depends on parameters like transmissivity, water retention in soil, transmission and absorption within plant, transpiration, atmospheric conditions and rain fall etc. Unavoidable irrigation losses due to Evapo transpiration, water application may need to be considered.

Irrigation requirement (IR) of a field is the sum total of irrigation need for an individual crop in a specified time plus the losses occurring in field distribution such as seepage, percolation etc. Irrigation frequency depends on crop consumptive use (CU) and the amount of available moisture in root zone. Sandy soils must be irrigated more often than fine textured deep soils. Irrigation period is the number of days that can be allowed for applying oneirrigation to a given area during the peak CU period.With the predefined water sources, main aim of irrigation scheduling is to obtain maximum production per unit water.

For the same crop, water requirement varies depending on type of soil and atmospheric conditions. In broader sense, the better classification of the areas for evaluating water requirement could be Humid, Semi Arid and Arid. As the methods of irrigation, rain fall and atmospheric conditions are not uniform across the state, region under consideration is taken as Semi Arid and crop water requirement is taken as in [5] for calculationsand the same is shown in Table III as depth of water required. In Table III Other crops include pulses, annual crops, horticulture crops, fruits and miscellaneous crops. For sesame, turmeric and chilies data is not found in the regions selected and appropriate values on higher side are considered for initiating the evaluation of net quantity of water to be applied.

Table III : Water requirement of crops in mm

Crop	Water required	Crop	Water required	Crop	Water required
Rice	1200	Turmeric	1000	Ground nuts	920
Wheat	650	Sugarcane	2700	Sesame	400
Jowar	950	Potatoes	900	Sunflower	500
Bajra	500	Sweet Potatoes	900	Soybean	680
Maize	1220	Onions	500	Tobacco	600
Ragi	450	Vegetables	750	Other crops	1250
Chilies	500	Cotton	1220		

For aiding calculations, it is considered that all the water required for crops is supplied through irrigation cycles only. Table IV shows the total area irrigated under different crops & Number of agricultural motors in six districts of APSPDCL for 2008-09, 2009-10 & 2010-11. Detailed crop wise list is available in season and crop report published by APDES.

Table IV : Area under Ground water irrigation & Number of sets Energized under APSPDCL districts [9]

Years → Districts ↓	2008-09		2009-10		2010-11	
	Area In Hectares	Number of Agricultural motors	In Hectares	Number of Agricultural motors	In Hectares	Number of Agricultural motors
Krishna	1,06,245	68,509	93,785	71,997	1,00,796	75,437
Guntur	1,04,363	60,219	1,15,284	63,226	1,28,756	66,840
Prakasam	1,12,396	92,566	1,13,941	96,408	1,26,101	1,01,645
Nellore	98,834	1,17,278	93,833	1,19,610	99,119	1,27,613
Kadapa	1,53,516	1,00,544	1,61,385	1,06,267	1,62,917	1,11,230
Chittor	1,63,117	2,38,496	1,72,123	2,49,630	1,75,612	2,62,994

Water heads for different districts for the same years is listed from the tables published by Ground water Board. Following is the list of data available in below ground water level (bgl). But in practical situations, these values cannot be considered for calculations as available heads. These values are on lower side and may not result in good estimates of power consumption.

Table V : Ground water levels in meters (bgl)

Districts → Years ↓	Krishna	Guntur	Prakasam	Nellore	Kadapa	Chittor
2009	6.85	4.75	4.92	4.27	7.23	8.4
2010	5.12	2.47	3.31	3.19	5.89	6.81
2011	4.54	2.90	3.65	3.24	5.99	6.33

III. Energy Requirement of Crops

Electrical Energy is required for crops to meet the irrigation requirement and in special cases for crop processing after the harvest. Scope of this paper is limited to evaluation of energy required for pumping water during irrigation scheduling only based on crop water requirement.

a) Estimation of Energy requirement based on actual water required

Year wise area irrigated with ground water is collected from Directorate of Economics & Statistics for listed crops and is used for calculations. Actual water required and energy required in cultivating crops is computed.

Upon knowing the actual water required in m^3, simple irrigator's equation helps in computing the time of irrigation when once the discharge is assumed.

$$A \times d = Q \times t \qquad (1)$$

Where A = Area under irrigation in m^2 d= depth of irrigation in m Q= discharge through pumpset in m^3/sec t= time required for irrigation.

Discharge through pipe in lit/sec is another parameter to be assumed. It is found that high water intense crops are usually cultivated in the regions where abundant ground water is available and the discharge would be through higher diameter pipe at high velocity.

Information regarding crop wise number of irrigation resources (pumps) is not available. Hence number of irrigation pumps under each crop during estimation is worked out as percentage of water required.

Upon knowing the time of irrigation and number of irrigation resources, district wise specific energy consumed can easily be estimated in kWh/hp. (Kilo Watt Hour / Horse Power)

$$\text{Consumption in kWh/hp} = \frac{t*0.745}{\%\text{Efficiency}} \quad (2)$$

Consumption in kWh/hp is also evaluated by modifying the number of pump sets with district wise Percentage of area irrigated in hectares. When the weighted average is taken for specific consumption based on amount of water required and area irrigated, value is found to be same. District wise results are presented from Table VI to Table VIII after estimation. Results of the proposed methodology are checked with the values given/projected by APSPDCL in Tariff Orders filings of respective years.

APDES collects district wise data every year for publishing several annual statistical reports. Data used for estimation in this paper is based on the reports from APDES and hence the estimates arevalidated.

Pump's discharge, number of pumpsets, hp ratings can be known exactly at the feeder level. It will lead to most reliable approximation with proposed calculations at micro level.

IV. Results & Discussions

As motors capacity is not known, with the help of number of motors and area under Ground water irrigation, year wise number of hectares per motor in APSPDCL districts is tabulated in Table VI.

Table VI : Year wise irrigated area: No. of hectares/ motor in APSPDCL districts

District → Year ↓	Krishna	Guntur	Prakasam	Nellore	Kadapa	Chittor
2008-2009	1.55	1.73	1.21	0.84	1.53	0.68
2009-2010	1.30	1.82	1.18	0.78	1.52	0.69
2010-2011	1.34	1.93	1.24	0.78	1.46	0.67

Table VII : District wise estimated specific consumption in kWh/hp

District → Year ↓	Krishna	Guntur	Prakasam	Nellore	Kadapa	Chittor	Average Units/hp
2008-2009	859.28	844.38	590.10	496.85	764.32	451.53	667.74
2009-2010	744.28	874.62	582.09	458.09	775.84	456.58	648.58
2010-2011	816.09	921.05	605.84	458.02	760.92	452.52	669.07

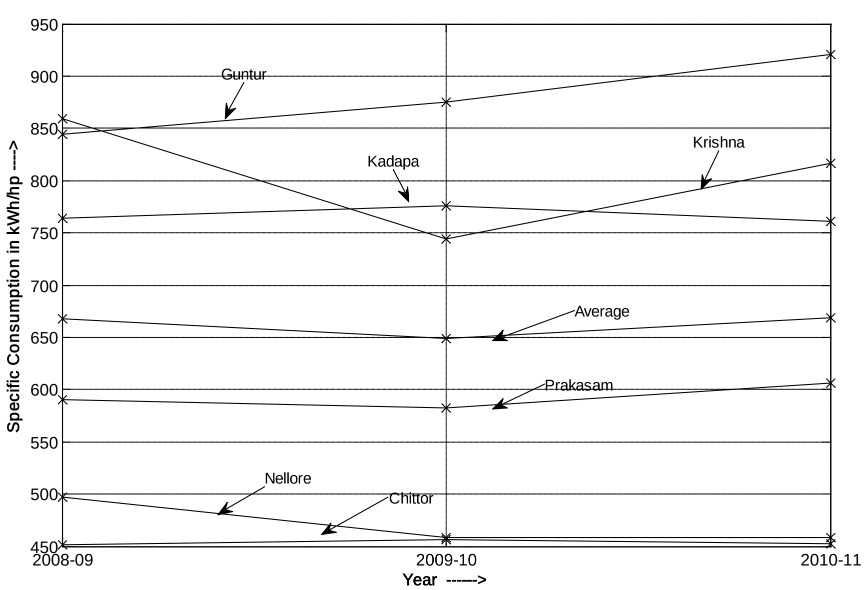

Figure 1 : Yer wise estimated specific consumption for six districts under APSPDCL

With year wise specific consumptions for all districts in Table VII,total consumption is estimated. Number of pumpsets are taken as per Table IV and district wise average hp indicated in Table VIII. District wise average hp is calculated as per the number of sets under paid category and is available in [7].

Table VIII : District wise errors in estimation with the data from APDES#[8]

Year → Districts ↓	2008-09			2009-10			2010-11		
	Agricultural Energy consumption in MU#	Estimated Consum-ption MU	%Error in Estimation MU	Agricultural Energy consumption in MU#	Estimated Consump-tion	% Error in Estimation	Agricultural Energy consumption in MU#	Estimated Consump-tion	%Error in Estimation
Krishna 4.67hp	252.20	274.92	-9.01	342.78	250.25	27.00	318.53	287.50	9.74
Guntur 4.72hp	267.19	240.00	10.18	301.00	261.01	13.29	294.23	290.58	1.24
Prakasam 5.18hp	576.56	282.95	50.92	647.00	290.70	55.07	470.83	318.99	32.25
Nellore4.28hp	449.56	249.40	44.52	523.00	234.51	55.16	560.06	250.16	55.33
Kadapa 9.01hp	989.51	692.40	30.03	1128.00	742.84	34.15	1064.70	762.58	28.38
Chittor6.17hp	1096.62	664.44	39.41	1255.00	703.23	43.97	1199.54	734.29	38.79
Total /Average 5.67hp	3631.64	2566.26	29.34	4196.78	2601.24	38.02	3907.89	2829.98	27.58

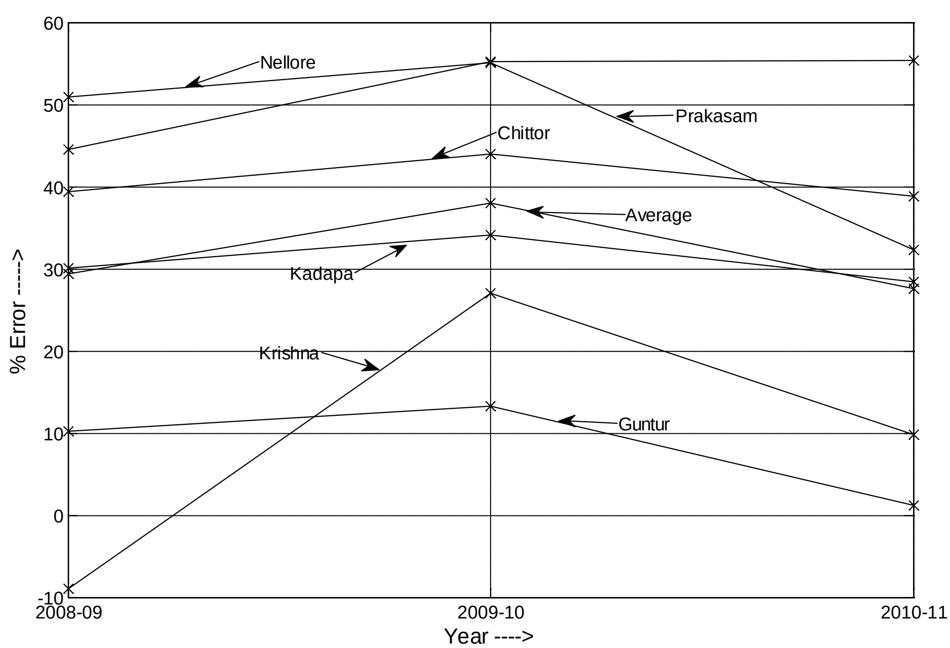

Figure 2 : Year wise % Error in estimation with data from [8]

Cumulative estimates of power consumption under all districts of APSPDCL are compared with the power consumption under agriculture category V. Total input to distribution network in MU is taken from Annual reports of respective years. Percentage of excess Consumption which may be going as losses and pilferage is calculated.

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Table IX : Estimation for the three years from values given by APSPDCL

Year →	2008-09	2009-10	2010-11
Total input to distribution network in MU	13805.48	15741.05	16449.08
Consumption Under LT Category V in MU	3459.25	4167.82	3664.49
Estimated value in MU	2566.26	2601.24	2829.98
Excess consumption in MU	892.99	1566.58	834.51
% of excess consumption reported	6.47%	9.95%	5.07%

V. Conclusions

With an aim of calculation of actual energy required to pump ground water in agricultural sector, district wise details of crops for different years are collected and the energy required is estimated. The estimation is carried out on the basis of actual water required. During computations, some parameters are assumed and the assumed values are presented. Requirement based estimation is most reliable study as it considers all the crops that are in source. To obtain results, all the water required for irrigation is assumed to be pumped through ground water only. Estimation is carried out for three years with the six districts under APSPDCL of Andhra Pradesh. District wise results are compared with the estimates published by APDES in year book s of respective years. DISCOM wise result is compared for three years with reference to consumption reported under category V. From results, Excess consumption reported by utilities can be reflected as Percentage of saving potential or amount of energy that unaccounted. Thisamount of unaccounted or loss energy would be of high value when the rain fall conditions are also taken into account. This estimation would produce most realistic value with micro level evaluation.

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Global Journal of Science Frontier Research
Agriculture and Veterinary
Volume 13 Issue 5 Version 1.0 Year 2013
Type : Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 2249-4626 & Print ISSN: 0975-5896

Infrastructural Growth, Farm Size and Pattern of Crop Diversification Across the Districts of West Bengal

By Utpal Kumar De
North-Eastern Hill University

Abstract - Scope of growth in employment and earning from agriculture through the expansion of area under cultivation in India as well as in West Bengal has been significantly reduced after nineteen seventies. The effects of Green Revolution technology on the yields of various crops have also decreased significantly as the growth of yield of various crops has reached a saturation level and simultaneously raised several environmental impacts after nineteen eighties. Thus, in any rural area including that of West Bengal the major option remains for the growth of agriculture is diversifying the land use for the cultivation of crops which are more remunerative and environment friendly.

Crop diversification thus became an important issue of research in agricultural economics not only within India and but also in other parts of the world. Choice of highly remunerative crops on the other hand depends on the availability of various agricultural technologies supported by appropriate infrastructure required for the timely cultivation, harvest, protection as well as marketing of those crops.

Keywords : *agro-infrastructure, agro-technology, crop diversification, robust regression, West Bengal.*

GJSFR-D Classification : *FOR Code: 300299p*

INFRASTRUCTURAL GROWTH, FARM SIZE AND PATTERN OF CROP DIVERSIFICATION ACROSS THE DISTRICTS OF WEST BENGAL

Strictly as per the compliance and regulations of :

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Keywords : agro-infrastructure, agro-technology, crop diversification, robust regression, West Bengal.

I. Introduction

Crop diversification has been projected as the solution to several problems associated with agriculture including sustainability of farm income, agricultural employment and management of soil productivity and reduction in fluctuation and uncertainty of farm earning (Minhas and Parikh, 1966; Bhalla and Alagh, 1979; Boyce, 1987; Dhindsa and Sharma, 1995; Vyas, 1996; Bhalla and Singh, 1997; De, 2001). It can also be viewed as the survival needs of the farmers especially of the small and marginal ones. But, the incidence of crop diversification in India was not significant before the introduction of new agricultural technology in the mid-nineteen sixties. With the advent of seed-fertilizer-irrigation technology a significant change in land allocation towards some high value cash crops, fruits and vegetables, particularly by the small farmers is observed in India (Joshi et. al, 2006). In West Bengal however, the diversification became prominent much later, only in 1980s (De, 2003).

The shifts in *cropping pattern* in India are traceable to changes in the relative prices of crops, expansion of irrigation and uses of technology that alter the relative profitability of crops in ways which affect different regions differently (Narain, 1965; Raj *et al* 1988). Development of infrastructure along with various price and other non-price factors are found responsible for the diversification of crops and hence a variation in growth of them caused significant spatial variation in the pace of crop diversification in India and West Bengal as well (Vyas, 1996; Chand, 1996; Narayanamoorthy, 1997; Singhal and Gauraha, 1997; Singh *et al*, 1997; Bhalla and Singh, 1997; De, 2003; De and Chattopadhyay, 2010). During 1980s and 1990s, the diversification has been wide-spread due to the supporting infrastructure development such as market centres, roads, transport etc., in the countryside along with seed-fertilizer-irrigation technology (Vyas, 1996; Bhalla and Singh, 1997).

Also, diversification is supposed to depend on the farm size as capacity to use technology, commercial motive and hence allocation of land towards cultivable crops depends on it and institutional factors. In the small peasant dominated Indian agriculture, availability of modern farm inputs during the recent decades helped even the small farmers to diversify land use towards high value crops and improve their earnings (GOI, 1997). In West Bengal, the high value crops like potato, summer paddy and mustard have received high priority among the farmers across all categories especially small farmers over the years (De, 2000). Diversification towards high value crops especially horticulture and some specific commercial crops like summer (boro) paddy, potato, mustard in the age of comer cialisation and improved market infrastructure help the farmers to earn cash as much as possible for the improvement of the standard of living.

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This paper examined the pattern of various infrastructure developments across the districts of West Bengal during 1970–71 to 2004–05.[1] Also the role of various infrastructural factors on the spatio-temporal variations in diversification is analysed. The next section presents a review of some relevant studies. Thereafter, the materials and methods used for the analysis are described, which is followed by observations and analysis. Finally, the conclusions of the study are presented.

II. Review of Relevant Literature

Literatures (Narain, 1965; Boyce, 1987; Narayanmoorthy, 1997; Sawant, 1997; Bhalla and Singh, 1997; Ashok and Balsubramania, 2006; De and Chattopadhyay, 2010) are available where the impact of various infrastructures; farm size, institutional factors, price, profitability etc on the diversification of crop at national or state level in India are examined. Chand (1995) observed that access to motorable road, market and irrigation facilities determines the success and profitability of diversification through high paying crops like off-season vegetables, while the role of farm size on the level of diversification were found to be very weak. Narain (1965), Nayyar and Sen (1994), Vyas (1996) on the other hand viewed that a significant change in the cropping pattern in the countryside was due to changes in the relative prices of the agricultural commodities. Also market infrastructure, institutional arrangements and technological change especially in irrigation contributed significantly to the changes in cropping pattern. However, Joshi and Gulati (2003) contradicted the argument and reported a negative impact of irrigation on crop diversification across the states of India during 1980-81 to 1999-2000.

With growing comer cialisation of Asian agriculture, diversification level of national production would go up while at farm level the diversification would go down due to more specialisation, though some other studies reported mixed effects of infrastructural variables on crop diversity (Trimmer, 1997). De (2000) also examined the extent of crop diversification and its variation across different districts of West Bengal with the help of various indices like *Herfindahl Index* (HI), *Ogive Index* (OI), *Entropy* (EI) as well as *Modified Entropy Index* (MEI) and observed large scale variations in diversification across districts over time depending upon the growth of utilisation of technologically improved agro-implements. Chand and Chauhan (2002) however, observed that the land possessed by the small and marginal peasants significantly related to the extent of diversification of crops in India during 1968-69 to 1998-99. Regressing DIV_{mk} as the index of diversification for two sub-periods; 1968-69 to 1983-84 and 1983-84 to 1998-99 on institutional credit per hectare Gross Cropped Area (GCA), electricity used in agriculture per hectare GCA, percentage of GCA under irrigation, agricultural markets per 1000 sq km area, road length per 1000 sq km area and proportion of small and marginal holdings as explanatory variables they found that only three variables irrigation, road density and small and marginal holdings had significantly positive impact on agricultural diversification.

A few authors have also argued that small and marginal farmers practised agricultural diversification instead of depending on the cereal based production only due to their survival. For example, a framework for assessing the flexibility of paddy lands and rice growers to respond to commercialization through seasonal or permanent diversification out of rice monoculture system has been developed by Pingali et al (1997). According to them, small and marginal farmers need diversification of crops for meeting their cost of living but the flexibility of farmers in responding to diversification opportunities is in most cases constrained by the size of markets, price risks, soil suitability, quality of irrigation infrastructure, availability and cost of labour. Using data from the South Asian countries, Joshi et al (2007) reported similar results. Small and marginal holders, despite having advantages of cheap family labour in contrast to the hired labour; to manage effectively in diversifying crops are in most cases constrained by the availability of market and fair price, and quality of irrigation infrastructure. Thus, in many cases they fail to achieve their targets of diversifying crops.

Ashok and Balsubramania (2006) showed the importance of infrastructure in explaining the extent of diversification. They observed that access to motorable road; market and irrigation determine the extent, success and profitability of diversification through high paying crops, while the role of farm size was insignificant.

De (2003) discussed at length the nature of changes in cropping pattern in West Bengal and the determinants of crop diversification during 1970-71 to 1994-95. In order to analyse the nature of changes in cropping pattern, he considered the rate of growth of acreage of different crops both in absolute and relative terms over time. The whole period was divided into two sub-periods: 1970-71 to 1981-82 and 1982-83 to 1994-95 to understand the variation in crop diversification during pre and post economic reforms scenario. The analysis revealed that the cropping pattern in West Bengal in terms of allocation of acreage remained skewed towards boro paddy, potato and oilseeds (especially mustard). These were the three important emerging cash crops during the decades of 1980's and 90's. The other crops continued to lose their importance in the cropping pattern of West Bengal. That means a concentration of crop activities in season has been observed towards a crop group that also varied across the districts over time. The primary reason for inter-

[1] This time period has been chosen as per the availability of data both at district and state level.

district variations in the intensity of crop diversification was the use of mechanical devices to exploit ground water as well as surface water and other scientific techniques have been growing faster in those so-called agriculturally developed districts such as Hooghly, Burdwan, Nadia and Howrah than the other areas.

In a similar regional study based on the data of Himachal Pradesh, Sharma (2005) argued that the adoption of high value cash crops, particularly fruit crops, helps the mountainous regions because it promotes the productive use of abundant marginal lands available in these regions. He analysed the patterns, processes and factors that facilitated the process of agricultural development and crop diversification, on the basis of secondary and primary data, collected from different districts of Himachal Pradesh. He also studied the temporal changes in the process of diversification through changes in share of area under non-foodgrain crops and by constructing and ranking of districts by using Herfindahl index that mainly captures distribution and diversity. But it is not enough to capture the changes in the enterprise mix over time. He has constructed another index that measures changes in the area allocated to different crops between two time periods as suggested by Chand and Chauhan (2002). Based on the above methodology, Sharma observed that there were inter-district variations in the level and extent of diversification and the process of crop diversification gathered momentum after 1987-88 all over the state.

Using the method of Minot (2003), Joshi, Birthal and Minot (2006) showed that the main source of crop income growth in India during 1980s was the technology led growth of yields of various crops and diversification emerged as the dominant sources of growth in agricultural income during the 1990s. Diversification towards horticultural crops led to rise in agricultural income in the 1990s more than that in the 1980s. Moreover, compared to the southern and western regions, impact of crop diversification was less in eastern region including West Bengal during the 1990s. At international level, Ahmad and Isvilanonda (2003) examined the regional pattern of diversification at farm level in the Thailand and also examined the impact of diversification on the farm income. Also they tried to find out the constraints faced by the farmers in different regions and production environment. The regional disparity in agricultural development has been observed due to the farmers' inability in certain regions to diversify relatively profitable crops.

Wehbe et al (2006) have shown that diversification of agricultural practices may be helpful in mitigating climate risk along with insurance, irrigation development and technologies that sometimes hindered due to the limitation of financial access, poor information network and market failures in Mexico and Argentina. Also differences in diversification and access to coping strategies between large and small farms have been a matter of concern and thus they advocated for the role of public sector.

In recent past, government of Tanzania also undertook a feasibility review for the diversification towards various horticultural crops and also for export diversification in order to reduce the impact of declining export earnings from cotton and coffee during the period of worldwide recession that affected mostly the small farmers who constitutes the majority of farming community. Those farmers also suffer from the lack of capital and other infrastructure needed for diversification (IDRC, 2008; CIAT, 2005).

III. Materials and Methods

First of all, variation in various agro-infrastructures across the districts and its temporal variation since 1970 have been described by tabular method. Changes in inter-district variation have been examined through the changes in coefficient of variation. As the data is available for some items only for few discrete years like minor irrigation items, electricity use, market and road infrastructure; the convergence level is examined by the correlation between the initial values across the districts and the rate of growth during the whole period ((Baumol 1986), DeLong (1988), Barro (1991), Barro and Sala-i-Martin (1992), and Mankiw et al. (1992)) though there are some limitations of this method as pointed out by Quah (1993), Bernard and Durlauf (1996), and Evans (1997). A significant negative correlation in this will indicate *convergence* in the growth across the districts, which happens if the initially backward districts grow at faster rates as compared to the relatively advanced districts. Wherever, continuous series of data is available like major irrigation, use of chemical fertiliser etc; cointegration coefficients have been checked to know the pattern of growth in the state (Johansen, 1988; Engle and Granger, 1987).

The convergence of the districts is observed if the co-integration coefficient is significant, which is examined by using augmented Engle-Granger (AEG) test through the regression

$$\Delta Y_{it} = \alpha_i + \beta_i \,.\, t + \gamma_{i0}\, Y_{i,\,t\text{-}1} + \sum_{j=1}^{p_i} \delta_{i,j}\, \Delta Y_{i,\ t\text{-}j} + \varepsilon_{it} \qquad (1)$$

where $t = 1, . . ., T$ ... (1). Here, Y_{it} is the series of error of regression of a time series say, irrigation intensity of one district on those of others. Here the inference is based on the usual τ-statistic of γ_{i0}, which has a non-standard distribution. The Akaike information criterion is used to determine the lag length parameter p_i. Equation is estimated in both forms, including and excluding time trend (Engle and Granger, 1987). Also, the coefficient of variation among the districts of irrigation intensity etc and its variation over time is computed. From the trend of coefficient of variation we can examine the

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convergence or divergence of the districts on that criterion.

The extent of crop diversification at a given point of time is examined by using various indices like, (1) Herfindahl Index (HI), (2) Simpson's Index (SI), (3) Entropy Index (EI) and (4) Modified Entropy Index (MEI). Among these indices the HI, SI and the entropy index are widely used in the literature of agricultural diversification. All these indices are computed on the basis of proportion of gross cropped area under different crops cultivated in a particular geographical area. It should be noted that the Herfindahl index is the index of concentration and thus the higher the value of it is an indication of specialisation of crop activities. Thus, it is subtracted from one to have the index of diversification, which is the simplified form of Simpson Index.[2]

A ranking of the districts on the basis of the computed values of these indices have been done to understand the spatial pattern of diversification. Again, to check whether the ranking pattern of the districts on the basis of these different indices are consistent or not, we have computed the spearman's rank correlation coefficient by taking the pairs of different indices and tested its level of significance. Here, the rank correlations are observed to be positive and significantly high for each pair of observations. Thus, without any loss of generality, any one of the indices can be used to describe the intensity of diversification. However, in the present study, analysis is made on the basis of computed Herfindahl indices so that the results can be compared with the earlier studies which have, by and large, used either Herfindahl index.

Since Herfindahl Index (HI) or Simpson Index assumes a very large (almost infinite) alternative of production choices, there exist a large number of crops which can be accommodated in measuring diversity by this index. Thus if the total area is equally shared among the large number of alternative crops, it means that the share of each crop would be exceedingly small and tending nearer to zero. The higher the value of HI, lower is the diversification and more is the concentration and vice versa. Here also the level of convergence of crop diversification among the districts is examined through the variation in coefficient of variation in Herfindahl Index over time as well as through cointegration coefficient of HI among the districts over time.

Data on area under crops, inputs used and various infrastructure facilities during the period of study across the districts in West Bengal have been collected from various issues of *Statistical Abstracts* and *District Statistical Handbooks* published by the Bureau of Applied Economics and Statistics, and Office of the Directorate of Agriculture, Government of west Bengal[4]

In order to find out the impact of different factors on the level of diversification over time in different parts of rural West Bengal, a multiple regression of the form $L_nHI = \beta_1 + \beta_2 \sum L_nX_i + U_i$ is performed. Here, HI is the Herfindahl Index and X_is are various infrastructures, technology and farm size related explanatory variables. The goodness of fit was, however, very poor which is due to the fact that HI takes values only between zero and one. Hence, the logit transformation of the dependent variable was tried out and that also did not yield good results. Finally, with the robust regression method by applying weighted median least squares on the logit *HI* and the three explanatory variables described above for the state as a whole throughout all the years, we obtained some reasonable results. However, for the case of inter-district variations in *HI* it could not be yielded good results due to very small degrees of freedom.

Among the several competing crops, allocation of area under three major crops (viz., paddy, potato and mustard) received high priority among the farmers over the years in West Bengal. It may be due to the farmers' expected profit from these crops relative to the other competitive crops and that has been guided by the expansion of several infrastructural and other factors. In order to examine the impact of different factors on the level of diversification over time in West Bengal, here the proportion of area under these three major growing crops, which have been responsible for changing diversification indices, are regressed on three variables like rainfall, proportion of GCA under canal irrigation and use of chemical fertiliser per unit of cropped area. These are the variables on which time series for the whole period are available at the district level as well as for the state as a whole. Here, log-linear specification i.e., Cobb-Douglas specification was adopted for the state as a whole. Using Dickey-Fuller test we found that dependent variables in all the cases follow stationary autoregressive process of order one and thus lagged (one period) endogenous variable was introduced as explanatory variable (Green, 2003). As time series information on other important explanatory infrastructure variables were not available for all the years under study these could not be included in the regression. Thus, finally district-wise growth of area under three fast growing crops during 1970-73 to 2002-05 (towards which high concentration was observed over time but at differential rates) was regressed on the growth of some selected explanatory variables for the same period. The similar log linear form was also adopted for running the regression.

[2] Here, the calculations are made for the composite districts of 24Paraganas, Midnapore and West Dinajpur. These districts were divided a few years back and the data on divided districts were not available separately for the early years of discussion. For the systematic analysis thus the combined figures for these composite districts have been calculated to make those comparable with their previous figures.

[4] Primary statistics of production, acreage and yield of various crops are collected from different districts of West Bengal and compiled and published by these departments on a regular basis.

IV. Observation and Analysis

a) *Growth of infrastructure in West Bengal*

The basic infrastructure required for the growth of agriculture has expanded disproportionately in West Bengal across space and time. Irrigation is one of the prime factors for the improvement of agricultural productivity and large scale irrigation comes from various canals constructed over the years and that helps farmers diversifying their cultivation towards more remunerative crops like potato, oilseeds and to adopt cultivation of summer paddy which is totally irrigation intensive. Here proportion of GCA under canal irrigation has been considered instead of net sown area (NSA) as some of the net irrigated area is cultivated during non-monsoon season without the availability of canal water and the pattern of crops are chosen accordingly. So, growth of NSA under irrigation does not reflect the true picture of growth of irrigation potential in West Bengal. Percentage of GCA under canal irrigation has increased from 11.32 per cent in 1971-74 to about 20 per cent in 2002-05. In the past three and half decades it has not been able to utilise the river water with full potential and thus though we observe occurrence of flood in some years there is shortage of water supply during the cultivation of draught season crops.

It has been observed that during 1970 to 2005 Burdwan, Birbhum, Hooghly, Bankura were among the top five districts while 24 Paraganas, Nadia, Malda, West Dinajpur and Cooch Behar were the bottom five districts in terms of percentage of GCA under canal irrigation. Inter-district variation in the coverage of canal irrigation though declined in 1980s, it increased again since 1990. Though due to the exhaustion of scope of canal irrigation expansion in the frontrunner districts the laggard districts have been found to expand relatively faster still now the advanced districts remain at the top layer due to the inherited canal irrigation infrastructure and limited scope in some of the districts like Nadia, Malda, West Dinajpur and Cooch Behar. The coefficient does not show a strong convergence of the districts in terms of growth of area under canal irrigation facilities.

As per the information available, ground water irrigation has expanded extensively through DTW and STW during 1979-80 to 1999-2000; initially with diesel engines and later on with electric motors. In case of minor irrigation a similar picture is observed except the fact that the districts (Nadia, Malda) where canal irrigations were limited also recorded significant growth of minor irrigation facilities (Table-2). Though the ground water irrigation capacity has expanded remarkably, the river lift irrigation (RLI) as well as canal irrigation has not been expanded satisfactorily and both are under the control of government. It is an indication of poor attention given in terms of investment for the development of river-based irrigation projects in West Bengal. In majority of the cases the growth rates of deep tube-well are much higher than that of RLI and shallow tube-well (STW). In the districts of Howrah, Hooghly, Birbhum, Burdwan, Midnapore and Murshidabad growth rates of STW are negative and in the former three districts it became nil due to failure of many STW to lift water and thus those have been converted to low capacity submersible pumps i.e., LTDW and other DTW with different capacities. However, in case of STW and RLI a significant convergence is observed, which is examined by the Karl Pearson's correlation between the initial values of the minor irrigation projects and the rates of growth during 1979-80 to 1999-2000 across the districts of West Bengal. This is because in the districts having more number of STW and RLI in the early years, have recorded a conversion towards DTWs of various capacities depending upon whether they are in individual capacity or cooperatives or government sponsored as well as exhaustion of RLI potential. Whereas in other districts, earlier RLI and relatively more expensive ground water irrigation potentials were not taped and have become economic with the growing necessity and market for irrigation and thus grew at relatively faster rate than those former districts.

In terms of use of chemical fertiliser along with organic manure West Bengal has progressed a long way and triennia average of it's consumption per hectare of GCA has increased from merely 13.65 kg in 1971-74 to 144.93 kg in 2002-05, i.e., it grew by over 961 per cent during past three decade (table-3). Hooghly, Howrah, Burdwan and Birbhum always remain within top five while Purulia, West Dinajpur and Jalpaiguri always remain within the bottom five throughout the period. If we look at the rate of growth, it appears that most of those districts initially using low chemical fertiliser per hectare of GCA recorded high rate of growth and vice versa. The correlation between the initial value across the districts and the rate of growth during the overall period is negative, which is an indication of the convergence of the intensity of use of chemical fertiliser. But most of the erstwhile advanced districts still remain relatively more advanced despite a minor change in the order and the coefficient of variation has not changed significantly, which indicates the weak level of convergence.

Table-4 represents the testing of cointegration of the districts in terms of trend of coefficient of variation in area under canal irrigation as well as intensity of chemical fertiliser use. It is also examined directly through the Augmented Engle-Granger test (AEG). Both the results are the indication of significant cointegration of the districts on both counts, i.e., a convergence of the districts in terms of application of irrigation and chemical fertiliser is observed. But if we look at the expansion of minor irrigation, whose data is not available for the continuous period a mixed result is observed.

Use of pump-sets replacing the traditional methods of lifting water for minor irrigation is important for the increase in capacity of minor irrigation, which played a crucial role for the expansion of cultivation of various winter and summer crops that are mostly commercial. It also helps irrigating crops during monsoon season in the erratic rainfall year. The use of diesel and electric pump-set in West Bengal has increased remarkably from a meagre 0.76 and 0.30 per thousand hectare of GCA in 1972 to 66.07 and 6.36 in 2003 respectively (tables-5, 6). Burdwan, Howrah, Hooghly and Nadia have been at the forefront in using pump set, diesel as well as electric while West Dinajpur, Darjeeling, Birbhum, Purulia, Jalpaiguri and Malda recorded comparatively low use of pump-sets in the irrigation but shown relatively faster growth in terms of use of those. In Hooghly however, over time, electric pump-set has outweigh the diesel pump-set in terms of growth with the increase in utilisation of electricity to increase the capacity of water-lifting and growth of DTW of various capacities. Overall, the expansion of use of electricity in West Bengal has not been satisfactory as compared to the use of diesel engine, which would otherwise increase the capacity of irrigation far more than whatever has been achieved so far. The correlation measures also show that the initially developed districts in terms of use of pump-sets (diesel as well as electric) remain in the front and the relatively backward districts though growing at a faster rate, they are still lagging and the negative correlations between the initial values and growth rates are the indications of weak level of convergence of the districts on both cases.

Howrah, Hooghly, Burdwan, 24 Paraganas are again the advanced districts in terms of use of tractor, power tiller etc for the tilling of soil replacing the erstwhile bullocks and traditional plough and mode of transport of harvested crops and marketing of the same. It helped farmers switch over to some highly remunerative commercial crops like potato, summer paddy and made possible to go for multiple cropping on a larger proportion of cultivable land conditioned by the simultaneous expansion of irrigation capacity at individual as well as cooperative level. In the state as a whole, the use of tractor has increased from merely 0.10 per thousand hectares of GCA in 1972 to 3.45 in 2003. On the other hand, use of power tiller has increased from 0.37 in number per thousand hectares of GCA to 2.90 during the same period that made land suitable for the cultivation of potato and some other crops, which was not possible manually to a large extent before the arrival of such technology (tables 7 and 8). The laggard districts like West Dinajpur, Bankura, Murshidabad, Midnapore, Jalpaiguri etc though growing at a faster rate, are still lagging behind the formerly advanced districts. The coefficient of variations in intensity of both though increased in 1970s and 1980s, those declined thereafter. Along with that the significant positive correlations of the values of different years indicate the similar result as we observed in case of irrigation and other infrastructure. The decline in values of positive correlation and coefficient of inter-district variation in recent decades is also reflected in the minor negative correlation between the initial year values and the overall growth rates during the whole period. Hence, a poor convergence level of the districts in the development of irrigation, fertiliser and cultivation infrastructure and adoption of modern techniques is observed.

The major black topping roads though not a precondition for the cultivation of major crops in West Bengal it helps timely marketing and earning remunerative price of the perishable crops. Road network in West Bengal has expanded by about 500 per cent during last three decade (table-9). Howrah, Hooghly from southern West Bengal and Darjeeling from the north have remained within top five districts in terms of growth of road network, while Midnapore, 24 Paraganas, Burdwan, Nadia have recorded much faster growth as compared to the state average. On the other hand, Malda, Cooch Behar and Purulia always remain within the bottom five positions and shown comparatively performance in terms of growth of road density.

In case of density of regulated market however, the North-Bengal districts have been in a better off position though there is big unregulated market competitiveness in the agriculturally developed southern part of the state (table-10). In case of both the road intensity and concentration of regulated market the advanced districts mostly remain advanced in the hierarchy and the laggard districts remain behind. But their growths have been convergent over time from the perspective of area. However, one may have a different result from the point of view of population and agricultural output.

Cold storage in West Bengal is used primarily for the preservation of perishable potato. It has not yet been developed for the other perishable crops like onion, vegetables, fruits, flowers or fishes. Hooghly, Burdwan, 24 Paraganas, Midnapore and Birbhum have been in the top five group in terms of the number of cold storage, while West Dinajpur, Nadia, Malda, Darjeeling, Purulia, Cooch Behar are the backward districts in terms of storage infrastructure and its growth over time, which is an indication of the divergence of growth across the districts (table-11).

Banking infrastructure especially the growth of regional rural and cooperative banks is viewed as the facilitators of financial liquidity through loan schemes so that the farmers especially the poor and marginal farmers can access and adopt various technology for the purpose of scientific cultivation and adopt appropriate crop pattern. Available information shows that per lakh population, since 1981 to 2000 there has been only 26 per cent growth in the state and there is significant variation in the growth across the districts. Despite the growth in absolute number; growth of bank branches per lakh population varied from -30.94 per cent in 24Paraganas to 104.29 per cent in Midnapore. Throughout the period, Howrah, Hooghly, Burdwan and Birbhum always remain at the top-five cluster, while Jalpaiguri, Cooch Behar, West Dinajpur, Midnapore and Murshidabad remain in the bottom cluster. But the districts in the bottom cluster achieved relatively faster growth and hence indicate some level of convergence.

b) Pattern of Crop Diversification

From the computed crop diversification indices (as presented in Table 13. In West Bengal we observe practically a high level of diversification towards some high value crops across the seasons over the years and there has been a wide district-wise variation of *Herfindahl, Simpson, Entropy and Modified Entropy* indices and all of them show a similar pattern for all the chosen years. Value of HI declined over time, which is an indication of more diversification. The significantly positive rank correlation between indices of various years indicate that the districts which were earlier at top in the early years in terms of these indices remained at the top in the later years also. Nadia, Murshidabad and Malda have always been within top five and Purulia, Birbhum, Bankura and 24Paraganas have always been within the bottom five districts in terms of diversification of crops. As HI represents the extent of concentration of crops and SI is calculated by deducting the HI from unity, we find similar correlations between any two chosen years for both the HI and SI. Similar is the case for entropy and modified entropy indices where the values are calculated only with different base values. But there is hardly any change in the number of crops cultivated except tea in a few northern districts of West Bengal and hence the ranking in terms of both these measures are found to be the same. Concentration towards a few crops has emerged over the years as this particular crop cycle yields maximum possible annual return from a particular plot of land (De, 2003; De and Chattopadhyay, 2010). Area under aman and boro paddy, potato and mustard together increased from about 64 per cent of GCA in 1970-73 to around 77 per cent in 2002-05 despite some inter-district variations, which might be presumed to be due to variation in growth of some important factors like use of chemical fertiliser, irrigation, agro-implements, electricity, land under different size-classes of holding etc or labour force.

Moreover, the coefficient of variation in the indices is very high due to the variation in number of crops cultivated in some districts owing to the specific agro-climatic conditions. For example, tea is cultivated extensively in three northern West Bengal districts Darjeeling, Jalpaiguri and Cooch Behar. While the southern districts like Burdwan, Hooghly, Howrah, Nadia concentrate more on three specific crops, namely aman paddy followed by potato or mustard in winter and then boro paddy during the summer in a crop cycle, which has been possible particularly due to the availability of minor irrigation in the off monsoon seasons and growing availability of technologically modern inputs, implements and other infrastructure. The relatively backward districts like Bankura, Purulia in terms of irrigation and other land improvement measures, follow a different cropping pattern suitable to the specific condition. However, majority of the farmers in different districts of West Bengal choose the cropping cycle in such a fashion that they can maximise their expected profit given the agro-climatic and other farming conditions including marketing facilities. If we look at the changes in coefficient of variations of the indices across the districts, it is observed to be on decline for the indices *SI, EI* and *MEI* over time but not statistically significant. It indicates that the laggard districts are gradually catching up with the developed districts in terms of diversification. In fact, the laggard districts gradually started getting benefit of several irrigation projects undertaken by the government, and also of the development of other infrastructures while the early advanced districts have been recording deceleration in the growth of those facilities as they have already reached the saturation level. Table 13a however shows the convergence of districts in terms of diversification of crops.

In order to examine the impact of different factors on the level of diversification over time in West Bengal, the results of robust weighted median least squares regression of Logit of HI on rainfall, chemical fertiliser per hectare of GCA and proportion of area under canal irrigation are presented below.

$$\text{Logit } HI_t = \underset{(1.19)}{12.526^*} - \underset{(0.0897)}{0.6279}\, L_n I_t^* + \underset{(0.01416)}{0.038}\, L_n CF_t^* - \underset{(0.03414)}{0.0548}\, L_n R_t^*$$

$$\text{Weighted } R^2 = 0.8146,\ F_{3,29} = 32.21,\ n = 33 \qquad (2)$$

[R_t, CF_t and I_t represent rainfall, use of chemical fertiliser per hectare of GCA and percentage of GCA under canal irrigation respectively. Figures within the parentheses represent standard error of the corresponding coefficient. Here, * and ** indicate that the coefficient is significant at one and five per cent level of significance by two tailed test].

Equation-2 shows that chemical fertiliser has significantly positive impact on the probability of concentration index while the canal irrigation and rainfall have negative impact on the same. Actually, availability and utilisation of chemical fertiliser made cultivation more remunerative for the fertiliser intensive cash crops like boro paddy and potato but rainfall (on which irrigation is also partly dependent) and irrigation especially in the off-monsoon season is essential for the expansion of diverse crop activities and led to the

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concentration of such crops over the years that is clear from its positive coefficients in respect of emerging crops of various seasons.

Now, the log linear regression of proportion of GCA under boro paddy, potato and mustard on the factors like rainfall, chemical fertiliser per hectare of GCA and proportion of area under canal irrigation are presented below.

For boro paddy:

$$L_nAB_t = -0.406 - 0.0695\ L_nR_t + 0.059\ L_nCF_t + 0.183\ L_nI_t^{**} + 0.0899\ L_nAB_{(t-1)}^{*}$$
$$(3.067)\quad (0.235)\quad (0.05)\quad (0.10)\quad (0.07)$$

$$\mathbf{R^2 = 0.989,\ R_{bar}^2 = 0.986,\ F = 583.88,\ D=1.55,\ n = 33} \qquad (3)$$

For mustard:

$$L_nAM_t = -1.397 - 0.238\ L_nR_t^{*} + 0.169\ L_nCF_t^{*} + 0.189\ L_nI_t^{**} + 0.674\ L_nAM_{(t-1)}^{*}$$
$$(2.085)\quad (0.076)\quad (0.062)\quad (0.16)\quad (0.11)$$

$$\mathbf{R^2 = 0.99,\ R_{bar}^2 = 0.989,\ F = 703.27,\ D=1.43,\ n = 33} \qquad (4)$$

For potato:

$$L_nAP_t = -0.219 - 0.166\ L_nR_t + 0.133\ L_nCF_t^{*} + 0.28\ L_nI_t^{*} + 0.785\ L_nAP_{(t-1)}^{*}$$
$$(2.96)\quad (0.222)\quad (0.052)\quad (0.099)\quad (0.064)$$

$$\mathbf{R^2 = 0.988,\ R_{bar}^2 = 0.987,\ F = 568.98,\ D=1.02,\ n = 33} \qquad (5)$$

In all the above three cases, availability and utilisation of chemical fertiliser and expansion of irrigation in general are found to have significant positive impact on the area under these crops. Both potato and boro paddy are highly irrigation and fertiliser intensive without which cultivation of these crops is almost impossible. Mustard as cultivated in winter season also depends on to some extent irrigation. Also, the demonstration effect generated for each year by the existing farmers on the decision to expand cultivation of these crops are also found significant as exhibited through the positive coefficient of the lagged value of the dependent variables. In fact, diversification of crops towards boro paddy, potato and mustard depends on minor irrigation which has been clearly indicated in table-14.

Information on some of the important infrastructure variables is available only for some specific years such as 1970, 1990 and 2005 at the district level. Role of these variables certainly has significant impact on the diversification as discussed above. Now, to examine the inter-district variations of these crops, the percentage variations in area under these three crops for the whole period are separately regressed on the percentage growth of some infrastructural variables across the districts in West Bengal. After thorough examination, only the relevant variables are included in the analysis to avoid the problem of degrees of freedom and multicollinearity. The estimated results are presented in tables- 14 and 15.

Results of table-14 shows that the growth of irrigation (both minor and major), use of electricity in agriculture measured by a proxy variable namely, number of electric pump-sets, storage facility have significant positive impact on the inter-district variations in growth of proportion of area under boro paddy in West Bengal during 1970-73 to 2002-05. Also, percentage of agricultural labour force to total working force and proportion of area under small and marginal farms have significant positive impact on inter-district variations. It indicates that the small and marginal farmers having limited cultivable land and no other sources of income try to adopt more and more multiple cropping and diversify land towards the cultivation of boro paddy instead of til, jute or other competing crops for their survival. This is supported by some infrastructural variables such as irrigation, electricity, availability of fertiliser; road density etc. Variations in growth of these factors across the districts are also evident. Though the small farmers do not own tractor, deep tube well, they try to avail the facilities of such technology from local informal markets. The impact of use of some machines such as tractor and tiller do not give any significant result because of the existence of multi-collinearity. However, use of power tiller is seen to be more prevalent in case of boro cultivation than the tractor owing to some user convenience in the fragmented plots of smaller holdings.

In case of potato (table-15), it is observed that the variations in intensity of chemical fertiliser use, storage capacity, intensity of minor irrigation has strong positive impact while tractor and power tiller, has positive but not highly significant impact on the growth of proportion of area under potato. As expected, market played a negative role in explaining the inter-district variations in diversification towards potato cultivation. Actually, potato market has always been speculative and exploited by the business groups in their favour. However, the growth of proportion of area under small and marginal farms showed a significant positive impact on the diversification towards potato, the fastest growing winter crop in the state of West Bengal.

Table-15 also reveals that variations in expansion of market, density of road are responsible for significant inter-district variations in diversification towards mustard over the years. Uses of fertiliser and minor irrigation show significant inverse relation in the context of inter-district variations in the growth of mustard cultivation. However, the growth of tractor and power tiller, storage facilities and proportion of cropped area under small and marginal farms has positive impact on mustard cultivation though not highly significant. Thus, the statistical results relating to mustard do not permit us to arrive at a firm conclusion regarding the factors responsible for diversification.

It is clear from the above results that size of holdings is one of the important factors explaining the extent of diversification at any rate in different districts of West Bengal. This is in conformity with the results obtained by some other researchers not only for India but for some other countries as well (Chand and Chauhan, 2002; Pingali et.al., 1997; Wehbe et.al., 2006; Joshi et.al, 2007; IDRC, 2008). The other infrastructural variables like irrigation, use of chemical fertiliser etc., are also important but the nature and extent of variations of these variables for different crops in different districts of West Bengal do not follow any rigid pattern. Hence it would be misleading to assume that they contribute in the same way for everywhere in the state. Existing studies, however, have failed to depict such reality.

V. Concluding Observations

Results suggest that there has been significant growth in infrastructure primarily in the front of irrigation, various implements for minor and major irrigation, agro-machinery and other implements and also to avail chemical fertiliser, transport, finance, storage etc. But the growth has been varied across the categories and over time across the districts. Major irrigation projects are maintained by the government, which is also dependent on the river networks, while minor irrigation facilities are primarily maintained by the individual farmers depending upon their resource strength and financial aid from various government organisations. District-wise variation in major irrigation intensity across the districts over time has been found to be comparatively higher than the intensity of fertiliser use. But the district-wise variation has been found to decline over time and the statistical measures suggest convergence of the districts on both terms. Moreover, the districts having less scope of canal irrigation recorded faster growth of minor irrigation. Compared to the irrigation and fertiliser use; electrification of agricultural practices, road, banking and storing infrastructures have not grown proportionately and in those cases poor level of convergence is observed.

The value of diversification indices in West Bengal has increased though not at a very faster rate but reallocation of land towards a few crops has been taking place continuously. Among the varieties of crops, the growth of summer or boro paddy, potato and mustard cultivation has been accelerating over the past three decades whereas the cultivation of wheat, other cereals, pulses, jute, sugarcane etc has been declining over the years. Data analysed separately for different sub-periods also confirm this phenomenon. The level of diversification has also been associated with the large scale inter-district variations. Interestingly, the level of diversification in the relatively backward agricultural districts like Bankura, Midnapore has taken place at relatively faster pace than the other advanced districts such as Burdwan, Hooghly etc. This is reflected through the decline in coefficient of inter-district variations in diversification indices over the years. However, it may be noted that the relatively advanced districts always maintained their relative positions in terms of diversification due to the better availability of agricultural and supporting infrastructure. Decline in coefficient of variation with respect to diversification indices over the years is an indication that the laggard districts where irrigation and other infrastructure have increased at relatively faster rate, could diversify at relatively faster pace than the hitherto advanced districts. The cointegration measures also suggest convergence of the districts in terms of diversification of crops.

Minor irrigation facilities supported by the electricity, storage and marketing facilities etc have played important roles with varied degrees for the diversification of crops and inter-district variation in diversification has been associated with those factors. Also, availability of fertiliser along with expansion of irrigation and agro-implements through raising yield of crops, helped in many cases to diversify the selected crops. Therefore, agricultural infrastructures are found to be crucial in promoting diversification of crops and ensure sustainable income and employment of the farmers. This explains as why small and marginal farmers who have limited land resources for maintaining minimum living standard diversify their crop cultivation. Though, growth of infrastructures has significant impact on the diversification, disparities in growth of such infrastructures lead to differences in diversification of crops towards boro paddy, potato and mustard. So-called political stability since the inception of Marxist government in West Bengal in 1977 and the new economic reforms in the 1990s have not been much helpful to alter the scenario of selective agricultural diversification in West Bengal.

In conclusion, therefore, it can be said that policies towards the expansion of infrastructure like road network, irrigation facilities through different modes wherever possible, marketing and storage facilities, power supply especially to the minor irrigation setups, availability of fertiliser, and facilitating those especially to

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the poor farmers are the important preconditions for the diversification of crops across the districts and future prospects of agriculture. As the poor farmers take the leading role here in diversification, markets and other infrastructure should be fair and competitive for their rational use by them. However, many of the poor farmers suffer from the lack of capital and thus provision of capital through cooperative and regional rural banks need to be well warranted.

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Table 1 : Percentage of GCA Under Canal Irrigation across Districts of West Bengal

1	2	3	4	5	6
District	1970-73	1979-82	1989-92	2002-05	Growth Rate during 1970-3 to 2002-5 (%)
Burdwan	46.59 (1)	44.86 (1)	45.09 (1)	38.80 (2)	-16.72 (12)
Birbhum	37.00 (2)	41.93 (2)	41.83 (3)	26.10 (3)	-29.47 (14)
Bankura	19.60 (4)	36.43 (3)	42.06 (2)	45.37 (1)	131.48 (6)
Midnapore	10.59 (5)	14.81 (5)	16.99 (5)	13.40 (6)	26.53 (8)
Howrah	3.52 (7)	3.26 (8)	3.37 (8)	11.95 (7)	239.93 (4)
Hooghly	27.40 (3)	25.08 (4)	22.91 (4)	21.90 (4)	-20.06 (13)
24Paraganas	0.00 (14)	0.00 (14)	2.81 (9)	2.42 (11)	0.00 (9)
Nadia	0.00 (15)	0.00 (15)	0.00 (15)	0.00 (15)	0.00 (10)
Murshidabad	7.92 (6)	8.10 (6)	8.04 (6)	5.23 (10)	-34.00 (15)
West Dinajpur	0.02 (12)	0.00 (12)	0.00 (13)	0.72 (12)	3444.09 (1)
Malda	0.00 (13)	0.00 (13)	0.00 (14)	0.00 (14)	0.00 (11)
Jalpaiguri	2.95 (9)	1.80 (10)	2.11 (10)	15.37 (5)	420.29 (3)
Darjeeling	3.33 (8)	2.90 (9)	2.02 (11)	5.36 (9)	60.72 (7)
Cooch Behar	0.06 (11)	0.03 (11)	0.16 (12)	0.17 (13)	202.66 (5)
Purulia	0.79 (10)	5.11 (7)	8.14 (7)	8.38 (8)	965.92 (2)
W B	**11.32**	**13.09**	**14.29**	**13.59**	**20.01**
C-V	67.07	70.56	49.12	61.75	75.58
Corr$_{ij}$	$R_{23} = 0.96$	$R_{24} = 0.24$	$R_{25} = 0.82$	$R_{45} = 0.91$	**$R_{26} = -0.29$**
Top five	Burdwan, Birbhum, Hooghly, Bankura, Midnapore	Burdwan, Birbhum, Hooghly, Bankura, Midnapore	Burdwan, Birbhum, Hooghly, Bankura, Midnapore	Bankura,Burdwan, Birbhum, Hooghly, Jalpaiguri	West Dinajpur, Purulia, Jalpaiguri, Howrah, Cooch Behar
Bottom five	Nadia, 24Paragana- s, Malda, West Dinajpur, Cooch Behar	Nadia, 24Paragana- s, Malda, West Dinajpur, Cooch Behar	Nadia, Malda, West Dinajpur, Cooch Behar, Darjeeling	Nadia, Malda, Cooch Behar, West Dinajpur, 24Paraganas	Murshidabad, Birbhum, Hooghly, Burdwan, Malda

Note: R_{ij} indicates correlation between column i and j.

Table 2 : Progress of Minor Irrigation Projects (Ground and River-lift Irrigation) in West Bengal under Government Minor Irrigation Schemes in West Bengal (Number)

	1979-80			1987-88			1994-95						1999-2000						Rate of Growth during 1979-80 to 1999-2000 (%)		
District	DTW	RLI	STW	DTW	RLI	STW	HDTW	MDTW	LDTW	Total DTW	RLI	STW	HDTW	MDTW	LDTW	Total DTW	RLI	STW	Total DTW	RLI	STW
Burdwan	301	237	408	332	266	408	447	24	176	647	259	101	547	38	344	929	276	93	208.64 (6)	16.46 (13)	-77.21 (7)
Birbhum	45	91	--	46	103	--	42	20	12	74	98		39	46	41	126	110	--	180.00 (7)	20.88 (12)	
Bankura	64	130	--	66	175	--	45	20	83	148	180	24	42	77	147	266	224	153	315.63 (5)	72.31 (7)	--
Midnapore	172	267	187	223	368	187	190	20	217	427	387	71	393	41	768	1202	425	1	598.84 (1)	59.18 (8)	-99.47 (8)
Howrah	89	56	30	93	95	30	79	20	--	99	91	--	96	53	--	149	111	--	67.42 (13)	98.21 (5)	--
Hooghly	240	260	361	261	316	361	312	17	276	605	304	80	412	44	879	1335	343	--	456.25 (2)	30.92 (9)	--
24-Paraganas	228	140	318	252	211	318	246	29	59	334	208	356	316	44	160	520	245	341	128.07 (9)	75.00 (6)	7.23 (5)
Nadia	517	272	600	532	319	600	591	32	228	851	299	758	660	33	293	986	330	827	90.72 (12)	21.32 (11)	37.83 (4)
Murshida bad	383	302	936	402	340	909	469	32	150	651	343	748	518	32	225	775	393	764	102.35 (11)	30.13 (10)	-18.38 (6)
West Dinajpur	116	270	200	134	345	200	308	11	--	319	333	407	280	18	18	316	314	1651	172.41 (8)	16.30 (14)	725.50(2)
Malda	128	353	239	164	381	239	257	11	24	292	347	232	266	18	6	290	347	1008	126.56 (10)	-1.70 (15)	321.76(3)
Jalpaiguri	33	27	--	33	71	--	46	--	--	46	77	202	59	--	84	143	122	1564	333.33 (4)	351.85 (2)	--
Darjeeling	1	11	--	1	23	--	--	--	--	--	23	--		--	--	0	27	147	-100.00 (14)	145.45 (3)	--
Cooch-Behar	15	23	90	15	88	90	30	--	--	30	95	252	68	--	--	68	244	1112	353.33 (3)	960.87 (1)	1135.56 (1)
Purulia	--	55	--	--	100	--	--	--	--	--	128	--		--	--	0	128		--	132.73 (4)	--
West Bengal	2332	2496	3369	2554	3198	3342	3062	236	1225	4523	3172	3231	3696	443	2965	7104	3739	7661	204.63	49.80	127.40
C-V	91.27	71.07	79.16	87.54	59.02	77.80	79.02	34.02	70.22	77.84	56.84	87.3	75.04	40.64	109.70	95.85	49.28	85.27	-0.08*	-0.55*	-0.54*

Sources: (i) Government of West Bengal, Directorate of agriculture,

(ii) Government of West Bengal, Directorate of Irrigation and Waterways.

Notes: (i) Figures relates to Minor Irrigation Schemes of the Government of west Bengal,

(ii) – indicates the value is nil.

(iii) DTW→ Deep tube well, STW→Shallow tube well, HDTW→ High capacity deep tube well LDTW→ Low capacity deep tube well, MDTW →Middle capacity deep tube well, RLI→River lift irrigation.

(iv) * Indicates the correlation between the initial (1979-80) values and the growth rates during 1979-80 to 1999-2000 across the districts.

Table 3 : District-wise Use of Chemical Fertilizer Per Hectare of GCA in West Bengal during 1971-4 to 2002-5 (Kg/Hec)

1	2	3	4	5	6
District	1971-74	1979-82	1989-92	2002-05	Growth Rate during 1971-74 to 2002-05 (%)
Burdwan	21.88 (4)	62.58 (3)	122.79 (4)	161.43 (7)	637.73 (10)
Birbhum	22.80 (3)	43.10 (4)	119.85 (5)	137.68 (10)	503.84 (13)
Bankura	19.90 (5)	30.93 (9)	69.53 (13)	136.40 (11)	585.36 (11)
Midnapore	9.29 (11)	30.34 (10)	74.16 (12)	131.01 (12)	1310.13 (6)
Howrah	30.19 (2)	110.96 (1)	252.36 (1)	421.31 (2)	1295.33 (7)
Hooghly	39.62 (1)	99.52 (2)	185.86 (2)	235.70 (3)	494.84 (14)
24Paraganas	12.86 (8)	32.98 (7)	92.02 (7)	170.66 (4)	1227.22 (9)
Nadia	15.76 (7)	44.53 (5)	85.59 (8)	90.32 (14)	472.94 (15)
Murshidabad	11.50 (9)	32.22 (8)	78.92 (10)	70.62 (15)	514.24 (12)
West Dinajpur	3.36 (15)	18.16 (13)	59.38 (15)	100.82 (13)	2903.93 (2)
Malda	10.01 (10)	31.09 (11)	103.61 (6)	139.08 (9)	1289.62 (8)
Jalpaiguri	5.83 (13)	11.36 (15)	64.58 (14)	166.10 (5)	2746.68 (3)
Darjeeling	16.40 (6)	33.04 (6)	125.28 (3)	462.14 (1)	2717.45 (4)
Cooch Behar	3.69 (14)	15.30 (14)	74.57 (11)	162.95 (6)	4310.04 (1)
Purulia	6.14 (12)	20.79 (12)	80.14 (9)	145.29 (8)	2266.13 (5)
W. B.	**13.65**	**36.89**	**94.54**	**144.93**	**961.55**
C-V	67.07	70.56	49.12	61.75	75.58
$Corr_{ij}$		$R_{23} = 0.91$	$R_{24} = 0.81$	$R_{25} = 0.44$	$R_{26} = -0.63$
Top five	Hooghly, Howrah, Birbhum, Burdwan, Bankura	Howrah, Hooghly, Burdwan, Birbhum, Nadia	Howrah, Hooghly, Darjeeling, Burdwan, Birbhum	Darjeeling, Howrah, Hooghly, 24Para-ganas, Jalpaiguri	Cooch Behar, West Dinajpur, Jalpaiguri, Darj- eeling, Purulia
Bottom five	Midnapore, Purulia, Jalpaiguri, Cooch Behar, West Dinajpur	Malda, Purulia, West Dinajpur, Cooch Behar, Jalpaiguri	Cooch Behar, Mid-napore, Bankura, Jalpaiguri, West Dinajpur	Bankura, Midnapore, West Dinajpur, Nadia, Murshidabad	Bankura, Murshidabad, Birbhum, Hooghly, Nadia

Note: R_{ij} indicates correlation between column i and j.

Table 4 : Testing Co-integration of the districts of West Bengal in terms of Expansion in proportion of GCA under Canal Irrigation and Growth of Chemical Fertiliser Use Per Hectare of GCA during 1970-71 to 2004-05

Item	Method	Criteria	Coeff.	T-value	Adj. R^2	F-Stat.	Log-likelihood	AIC	Max -lag	Remark
Canal Irrigation	Sty. of CV of Dists.	Level	-0.144	-1.59	0.044	2.53	-113.45	6.79	8	No Co-int.
		1st Diff.	-1.236	-7.031	0.602	49.44	-110.93	6.844	8	Co-integrated
	AEG	Level	-1.779	-6.726	0.684	35.63	-28.374	1.901	8	Co-integrated
		1st Diff.	-6.133	-5.71	0.868	37.75	-27.582	2.316	8	Co-integrated
Chem. Fertiliser	Sty. of CV of Dists.	Level	-0.72	-4.173	0.34	17.42	-143.11	8.795	8	Co-integrated
		1st Diff.	-1.42	-8.59	0.701	73.79	-143.23	9.077	8	Co-integrated
	AEG	Level	-1.27	-7.308	0.621	53.40	-91.86	5.688	8	Co-integrated
		1st Diff.	-3.10	-6.026	0.838	50.84	-88.08	6.139	8	Co-integrated

Notes: (1) Critical value at 1% level = -3.639, at 5% level = -2.951, at 10% level = -2.614

(2) Sty. Indicates stationarity, AEG indicates Augmented Engle-Granger test.

Table 5 : District-wise Diesel Pump-sets per thousand hectare of GCA in West Bengal

1	2	3	4	5	6	7
District	**1972**	**1982**	**1989**	**1994**	**2003**	Growth Rate during 1972 to 2003 (%)
Burdwan	0.87 (4)	45.30 (3)	64.35 (5)	74.55 (5)	58.00 (9)	6541.90 (10)
Birbhum	0.16 (14)	18.05 (9)	39.89 (8)	56.41 (7)	53.41 (11)	33515.01 (3)
Bankura	0.27 (10)	20.49 (8)	36.68 (9)	50.40 (10)	92.07 (2)	34121.98 (2)
Midnapore	0.91 (3)	31.92 (6)	72.22 (3)	56.30 (8)	96.33 (1)	10475.70 (8)
Howrah	8.68 (1)	32.26 (5)	47.71 (7)	54.63 (9)	54.08 (10)	522.95 (15)
Hooghly	1.75 (2)	104.55 (1)	86.74 (1)	84.10 (1)	60.92 (8)	3372.03 (12)
24Paraganas	0.74 (5)	42.55 (4)	70.41 (4)	70.87 (6)	71.68 (4)	9592.42 (9)
Nadia	0.66 (6)	46.74 (2)	74.86 (2)	82.22 (2)	75.88 (3)	11325.66 (7)
Murshidabad	0.51 (7)	21.38 (7)	54.20 (6)	76.24 (4)	69.12 (5)	13345.41 (6)
West Dinajpur	0.25 (11)	5.60 (11)	23.75 (10)	37.51 (11)	64.46 (7)	25999.89 (4)
Malda	0.17 (12)	11.49 (10)	16.94 (11)	81.04 (3)	67.44 (6)	39286.78 (1)
Jalpaiguri	0.44 (8)	0.00 (14)	3.39 (13)	8.38 9 (13)	19.70 (14)	4394.18 (11)
Darjeeling	0.17 (13)	0.00 (15)	3.80 (12)	0.92 (15)	1.88 (15)	1015.49 (14)
Cooch Behar	1.37 (9)	3.90 (12)	2.97 (14)	25.13 (12)	41.71 (12)	2946.86 (13)
Purulia	0.11 (15)	3.71 (13)	2.70 (15)	7.18 (14)	20.15 (13)	18248.58 (5)
W. B.	**0.76**	**28.19**	**47.80**	**57.43**	**66.07**	**8649.29**
C-V	188.18	105.38	74.44	56.68	46.66	90.68
$Corr_{ij}$		$R_{23} = 0.22$	$R_{24} = 0.19$	$R_{25} = 0.11$	$R_{26} = 0.02$	$R_{27} = -.41$
Top 5 Districts	Howrah, Hooghly, Midnapore, Burdwan, 24Paraganas	Hooghly, Nadia, Burdwan, 24Paraganas, Howrah	Hooghly, Nadia, Midnapore, 24Paraganas, Burdwan	Hooghly, Nadia, Malda, Murshidabad Burdwan	Midnapore, Bankura, Nadia, 24Paraganas, Murshidabad	Malda, Bankura, Birbhum WestDinajpur, Purulia
Bottom 5 Districts	WestDinajpur, Malda, Darjeeling, Birbhum, Purulia	WestDinajpur, CoochBehar, Purulia, Jalpaiguri, Darjeeling	Malda, Darjeeling, Jalpaiguri, CoochBehar, Purulia	WestDinajpur, Cooch Behar, Jalpaiguri, Purulia, Darjeeling	Birbhum, CoochBehar, Purulia, Jalpaiguri, Darjeeling	Jalpaiguri, Hooghly, CoochBehar, Darjeeling, Howrah
Note: R_{ij} indicates correlation between column i and j.						

Table 6 : Districtwise Use of Electric Pump-Set per thousand hectare of GCA in West Bengal

1	2	3	4	5	6	7
District	**1972**	**1982**	**1989**	**1994**	**2003**	Rate of Growth during 1972 to 2003 (%)
Burdwan	0.68 (2)	2.19 (3)	5.18 (6)	9.27 (3)	10.40 (2)	1418.32 (8)
Birbhum	0.09 (11)	1.01 (7)	6.53 (4)	11.06 (2)	10.71 (1)	11570.44 (2)
Bankura	0.14 (8)	0.29 (10)	1.39 (10)	7.56 (5)	5.36 (8)	3683.29 (4)
Midnapore	0.10 (9)	1.94 (5)	3.99 (8)	3.67 (6)	6.03 (7)	5797.97 (3)
Howrah	0.70 (3)	1.74 (6)	11.04 (2)	0.61 (13)	1.46 (13)	108.90 (15)
Hooghly	0.01 (14)	3.98 (2)	7.98 (3)	7.42 (7)	9.78 (4)	152018.18 (1)
24Paraganas	0.26 (6)	2.09 (4)	5.83 (5)	7.24 (8)	6.38 (6)	2363.27 (6)
Nadia	1.05 (1)	10.30 (1)	15.19 (1)	18.64 (1)	10.09 (3)	859.65 (13)
Murshidabad	0.58 (4)	0.58 (8)	5.09 (7)	8.02 (4)	8.10 (5)	1295.22 (9)
West Dinajpur	0.18 (7)	0.21 (12)	1.05 (11)	2.28 (10)	2.21 (12)	1140.53 (11)
Malda	0.31 (5)	0.29 (11)	2.73 (9)	3.63 (9)	3.46 (9)	1005.52 (12)
Jalpaiguri	0.10 (10)	0.00 (14	0.51 (12)	0.68 (12)	2.27 (11)	2109.29 (7)
Darjeeling	0.01 (12)	0.00 (15)	0.00 (15)	0.12 (15)	0.08 (15)	546.21 (14)
Cooch Behar	0.04 (13)	0.58 (9)	0.20 (13)	0.80 (11)	0.54 (14)	1184.19 (10)
Purulia	0.00 (15)	0.10 (13)	0.18 (14)	0.43 (14)	3.46 (10)	3431.88 (5)
W. B.	**0.30**	**1.87**	**4.64**	**6.28**	**6.36**	**2051.58**
C-V	112.91	156.16	99.23	95.48	70.21	307.78
$Corr_{ij}$		R_{23} = 0.66	R_{24} = 0.76	R_{25} = 0.60	R_{26} = 0.38	**R_{27} = -.26**
Top 5 Districts	Nadia, Burdwan, Howrah, Murshidabad, Malda	Nadia, Hooghly, Burdwan, 24Parag, Midnapore	Nadia, Howrah, Hooghly, Birbhum, Midnapore	Nadia, Birbhum, Burdwan, Murshidabad, Bankura	Birbhum, Burdwan, Nadia, Hooghly, Murshidabad	Hooghly, Birbhum, Midnapore, Bankura, Purulia
Bottom 5 Districts	Birbhum, Darjeeling, CoochBehar, Birbhum, Purulia	Malda, WestDinajpur, Purulia, Jalpaiguri, Darjeeling	WestDinajpur, Jalpaiguri, CoochBehar, Purulia, Darjeeling	CoochBehar, Jalpaiguri, Howrah, Purulia, Darjeeling	Jalpaiguri, WestDinajpur, Howrah, CoochBehar, Darjeeling	WestDinajpur, Malda, Nadia, Darjeeling, Howrah

Note: R_{ij} indicates correlation between column i and j.

Table 7 : District-wise Use of Tractor per thousand hectare of GCA in West Bengal

1	2	3	4	5	6	7
District	**1972**	**1982**	**1989**	**1994**	**2003**	Rate of Growth during 1972 to 2003 (%)
Burdwan	0.23 (2)	1.49 (1)	3.82 (1)	4.89 (2)	9.45 (3)	3946.36 (4)
Birbhum	0.14 (5)	0.14 (6)	0.69 (5)	1.32 (7)	2.66 (6)	1757.64 (12)
Bankura	0.03 (14)	0.05 (8)	0.57 (6)	1.37 (6)	4.09 (5)	14071.95 (2)
Midnapore	0.04 (13)	0.09 (7)	0.33 (10)	0.52 (11)	1.22 (13)	2688.35 (8)
Howrah	0.35 (1)	0.41 (3)	0.83 (4)	3.00 (3)	9.60 (2)	2679.37 (9)
Hooghly	0.06 (10)	0.98 (2)	1.53 (2)	5.32 (1)	11.66 (1)	18049.39 (1)
24Paraganas	0.15 (4)	0.27 (4)	0.48 (8)	1.44 (5)	4.24 (4)	2645.32 (10)
Nadia	0.13 (6)	0.18 (5)	0.86 (3)	1.45 (4)	2.62 (7)	1881.89 (11)
Murshidabad	0.06 (11)	0.04 (10)	0.25 (11)	0.58 (9)	1.99 (9)	3051.02 (5)
West Dinajpur	0.03 (15)	0.04 (11)	0.52 (7)	0.44 (12)	1.77 (10)	5383.68 (3)
Malda	0.08 (8)	0.05 (9)	0.00 (14)	0.61 (8)	2.35 (8)	2815.23 (7)
Jalpaiguri	0.16 (3)	0.00 (14)	0.35 (9)	0.34 (13)	1.21 (14)	631.88 (14)
Darjeeling	0.07 (9)	0.00 (15)	0.00 (15)	0.55 (10)	0.30 (15)	312.86 (15)
Cooch Behar	0.05 (12)	0.02 (13)	0.12 (13)	0.27 (14)	1.44 (11)	2913.28 (6)
Purulia	0.10 (7)	0.04 (12)	0.17 (12)	0.17 (15)	1.39 (12)	1286.32 (13)
W. B.	**0.10**	**0.27**	**0.74**	**1.45**	**3.59**	**3476.50**
C-V	77.78	167.78	135.39	110.44	95.19	117.02
$Corr_{ij}$		$R_{23} = 0.43$	$R_{24} = 0.43$	$R_{25} = 0.44$	$R_{26} = 0.52$	**$R_{27} = -0.31$**
Top 5 Districts	Howrah, Burdwan, Jalpaiguri, 24Paraganas, Birbhum	Burdwan, Hooghly, Howrah, 24Paraganas, Nadia	Burdwan, Hooghly, Nadia, Howrah, Birbhum	Hooghly, Burdwan, Howrah, Nadia, 24 Paraganas	Hooghly, Howrah, Burdwan, 24Paraganas, Bankura	Hooghly, Bankura, WestDinajpur Burdwan, Murshidabad
Bottom 5 Districts	Murshidabad, CoochBehar, Midnapore, Bankura, WestDinajpur	WestDinajpur, Purulia, Cooch Behar Jalpaiguri, Darjeeling	Murshidabad, Purulia, CoochBehar, Malda, Darjeeling	Midnapore , WestDinajpur, Jalpaiguri, CoochBehar, Purulia	CoochBehar, Purulia, Midnapore, Jalpaiguri, Darjeeling	Nadia, Birbhum Purulia, Jalpaiguri, Darjeeling

Note: R_{ij} indicates correlation between column i and j.

Table 8 : District-wise Use of Power Tiller per thousand hectare of GCA in West Benga

1	2	3	4	5	6
District	1982	1989	1994	2003	Rate of Growth during 1982 to 2003 (%)
Burdwan	0.32 (4)	1.15 (4)	1.42 (5)	4.21 (3)	1214.34 (7)
Birbhum	0.11 (6)	0.26 (8)	0.37 (9)	0.49 (12)	363.31 (12)
Bankura	0.06 (9)	0.11 (10)	1.30 (6)	3.36 (4)	5825.64 (1)
Midnapore	0.14 (5)	1.63 (3)	2.47 (3)	7.24 (2)	5098.46 (2)
Howrah	2.49 (2)	3.43 (2)	8.32 (1)	2.29 (7)	-7.97 (15)
Hooghly	4.43 (1)	7.21 (1)	5.21 (2)	7.36 (1)	66.09 (13)
24Paraganas	0.33 (3)	0.96 (5)	1.59 (4)	3.20 (5)	878.94 (10)
Nadia	0.07 (8)	0.27 (7)	1.00 (7)	1.10 (9)	1450.42 (6)
Murshidabad	0.02 (12)	0.05 (12)	0.09 (13)	0.41 (13)	2086.47 (4)
West Dinajpur	0.01 (13)	0.02 (13)	0.17 (12)	0.53 (11)	4458.14 (3)
Malda	0.11 (7)	0.32 (6)	0.25 (11)	2.31 (6)	1987.04 (5)
Jalpaiguri	0.00 (14)	0.14 (9)	0.35 (10)	1.41 (8)	910.53 (9)
Darjeeling	0.00 (15)	0.00 (15)	0.00 (15)	0.17 (15)	0.00 (14)
Cooch Behar	0.06 (10)	0.07 (11)	0.84 (8)	0.79 (10)	1167.90 (8)
Purulia	0.03 (11)	0.00 (14)	0.00 (14)	0.18 (14)	426.43 (11)
W. B.	**0.37**	**0.95**	**1.40**	**2.90**	**677.39**
C-V	227.94	186.26	147.83	101.72	109.52
$Corr_{ij}$		$R_{23} = 0.98$	$R_{24} = 0.81$	$R_{25} = 0.56$	$R_{26} = -0.35$
Top 5 Districts	Hooghly, Howrah, 24Paraganas, Burdwan, Midnapore	Hooghly, Howrah, Midnapore, Burdwan, 24Paraganas,	Howrah, Hooghly, Midnapore, 24Paraganas, Burdwan	Hooghly, Midnapore, Burdwan, Bankura, 24 Paraganas	Bankura, Midnapore, WestDinajpur, Murshidabad, Malda
Bottom 5 Districts	Purulia, Murshidabad, WestDinajpur, Jalpaiguri, Darjeeling	CoochBehar, Murshidabad, WestDinajpur, Purulia, Darjeeling	WestDinajpur Murshidabad, Nadia, Purulia, Darjeeling	WestDinajpur Birbhum, Murshidabad, Purulia, Darjeeling	Purulia, Birbhum, Hooghly, Darjeeling, Howrah

Note: R_{ij} indicates correlation between column i and j.

Table 9 : District-wise Road Length in West Bengal Maintained by PWD, Municipality and all Panchayats Per Sq Km area

1	2	3	4	5	6
District	**1980**	**1990**	**2000**	**2003**	**Rate of Growth during 1973-2000**
Burdwan	21.35 (11)	6101 (5)	74.14 (7)	189.50 (7)	787.38 (3)
Birbhum	43.53 (5)	51.21 (7)	63.97 (10)	157.03 (9)	260.75 (11)
Bankura	30.37 (8)	35.07 (12)	35.92 (15)	129.37 (10)	325.98 (7)
Midnapore	13.17 (15)	52.63 (6)	60.12 (11)	209.84 (4)	1493.28 (1)
Howrah	139.41 (1)	170.02 (2)	187.00 (3)	466.21 (1)	234.42 (12)
Hooghly	76.55 (3)	116.40 (3)	298.88 (2)	285.27 (3)	272.63 (10)
24Paraganas	16.88 (14)	46.34 (9)	92.53 (5)	204.14 (5)	1109.23 (2)
Nadia	22.92 (10)	70.78 (4)	94.35 (4)	193.61 (6)	744.66 (4)
Murshidabad	44.09 (4)	2803 (14)	83.50 (6)	184.03 (8)	317.42 (8)
WestDinajpur	34.44 (7)	44.04 (10)	38.96 (13)	109.60 (11)	218.26 (14)
Malda	16.92 (13)	47.26 (8)	53.64 (12)	56.22 (15)	232.24 (13)
Jalpaiguri	27.70 (9)	34.29 (13)	36.49 (14)	109.19 (12)	294.24 (9)
Darjeeling	10392 (2)	371.59 (1)	414.25 (1)	443.12 (2)	326.40 (6)
Cooch Behar	40.75 (6)	36.65 (11)	72.14 (8)	66.92 (14)	64.21 (15)
Purulia	19.91 (12)	23.34 (15)	66.34 (9)	106.11 (13)	433.05 (5)
W. B.	29.26	54.66	82.15	174.27	495.69
C-V	83.10	112.80	97.01	62.78	82.65
Corr$_{ij}$		$R_{23} = 0.75$	$R_{24} = 0.74$	$R_{25} = 0.85$	**$R_{26} = -0.42$**
Top 5 Districts	Howrah, Darjeel- ing, Hooghly, Murshidabad, Birbhum	Darjeeling, Hooghly, Murshidabad, Nadia, Burdwan	Darjeeling, Hooghly, Howrah, Nadia, 24Paraganas	Howrah, Darjee-ling, Hooghly, Midnapore, 24Paraganas	Midnapore, 24Paraganas, Burdwan, Nadia, Purulia
Bottom 5 Districts	Burdwan, Purulia, Malda, 24Paraganas, Midnapore	CoochBehar, Bank- ura, Jalpaiguri, Mu- rshidabad, Purulia	Midnapore, Malda, WestDinajpur, Jalpaiguri, Bankura	WestDinajpur, Jalpaiguri, Purulia, CoochBehar,Malda	Birbhum, Howrah, Malda, WestDinajpur, CoochBehar

Note: R_{ij} indicates correlation between column i and j.

Table 10 : District-wise Total Regulated Market in West Bengal per 1000 Sq Km

1	2	3	4	5	6
District	1989	1994	1997	2000	Growth Rate during 1989 to 2000 (%)
Burdwan	5.14 (4)	5.14 (8)	6.42 (6)	6.42 (6)	25.00 (9)
Birbhum	0.44 (14)	1.77 (13)	1.77 (15)	3.99 (10)	800.00 (1)
Bankura	1.60 (11)	2.48 (11)	2.48 (11)	2.48 (13)	54.55 (7)
Midnapore	1.10 (13)	1.69 (14)	2.35 (12)	2.50 (12)	126.67 (5)
Howrah	4.14 (5)	4.83 (9)	4.83 (9)	4.83 (9)	16.67 (12)
Hooghly	23.21 (3)	23.53 (3)	27.66 (3)	27.98 (3)	20.55 (10)
24Paraganas	0.00 (15)	2.33 (12)	2.33 (13)	2.33 (14)	0.00 (14)
Nadia	2.30 (9)	2.56 (10)	2.56 (10)	3.07 (11)	33.33 (8)
Murshidabad	2.79 (6)	5.78 (6)	5.59 (7)	5.78 (7)	106.67 (6)
West Dinajpur	2.43 (7)	5.43 (7)	7.68 (5)	8.05 (5)	230.77 (3)
Malda	1.94 (10)	9.71 (5)	5.55 (8)	5.27 (8)	171.43 (4)
Jalpaiguri	2.43 (8)	9.90 (4)	9.74 (4)	9.90 (4)	306.67 (2)
Darjeeling	25.03 (2)	28.60 (2)	28.60 (2)	27.41 (2)	9.52 (13)
Cooch Behar	33.40 (1)	32.81 (1)	32.22 (1)	32.81 (1)	-1.75 (15)
Purulia	1.60 (12)	1.60 (15)	2.25 (14)	1.92 (15)	20.00 (11)
W. B.	4.03	5.92	6.28	6.46	60.23
C-V	148.56	112.65	112.50	109.02	162.30
$Corr_{ij}$		R_{23} = 0.97	R_{24} = 0.98	R_{25} = 0.98	R_{26} = - 0.33
Top 5 Districts	CoochBehar, Dar- jeeling, Hooghly, Burdwan, Howrah	CoochBehar, Dar- jeeling, Hooghly, Jalpaiguri, Malda	CoochBehar, Darj- eeling, Hooghly, Jalpaiguri, West Dinajpur	CoochBehar, Darjeeling, Hooghly, Jalpaiguri, WestDinajpur	Birbhum, Jalpaiguri, WestDinajpur, Malda, Midnapore
Bottom 5 Districts	Bankura, Purulia, Midnapore, 24Paraganas,	Bankura, 24Paraganas, Birbbhum, Midnapore, Purulia	Bankura, Midnapore, 24Paraganas Purulia, Birbhum	Nadia, Midnapore, Bankura, 24Paraganas, Purulia	Purulia, Howrah, Darjeeling, 24Paraganas, CoochBehar

Note: R_{ij} indicates correlation between column i and j.

Table 11 : District-wise Number of Cold Storage in West Bengal

1	2	3	4
District	**1969-70**	**2006-07**	**Growth Rate 1969-70 to 2006-07**
Burdwan	27 (2)	102 (2)	277.78 (4)
Birbhum	6 (5)	16 (6)	166.67 (6)
Bankura	2 (8)	41 (4)	1950.00 (2)
Midnapore	7 (3)	57 (3)	714.29 (3)
Howrah	4 (7)	9 (9)	125.00 (7)
Hooghly	45 (1)	133 (1)	195.56 (5)
24Paraganas	6 (4)	7 (10)	16.67 (9)
Nadia	0 (12)	3 (12)	--
Murshidabad	5 (6)	11 (8)	120.00 (8)
West Dinajpur	0 (11)	5 (11)	--
Malda	0 (13)	3 (13)	--
Jalpaiguri	1 (9)	25 (5)	2400.00 (1)
Darjeeling	0 (14)	1 (14)	--
Cooch Behar	0 (10)	12 (7)	--
Purulia	0 (15)	0 (15)	--
W. B.	103	425	312.62
C-V	183.13	140.87	--
$Corr_{ij}$		$R_{23} = 0.93$	$R_{24} = -0.08$
Top 5 Dist.	Hooghly, Burdwan, Midnapore, 24Para-ganas, Birbhum,	Hooghly, Burdwan, Midnapore, Bankura, Jalpaiguri	Jalpaiguri, Bankura, Midnapore, Burdwan, Hooghly
Bottom 5 Dist.	West Dinajpur, Nadia, Malda, Darjeeling, Purulia, Cooch Behar	West Dinajpur, Nadia, Malda, Darjeeling, Purulia	Purilia, Darjeeling, Malda, Nadia, West Dinajpur
Note: R_{ij} indicates correlation between column i and j.			

Table 12 : District-wise Number of Bank Branches Per Lakh Population since 1981

1	2	3	4	5
District	1981	1991	2000	Growth Rate 1981-to 2000
Burdwan	3.85 (4)	5.88 (3)	5.00 (3)	29.87 (8)
Birbhum	4.35 (3)	6.67 (2)	5.56 (2)	27.82 (10)
Bankura	2.63 (10)	5.88 (4)	5.00 (4)	90.11 (2)
Midnapore	2.33 (12)	5.56 (7)	4.76 (7)	104.29 (1)
Howrah	4.35 (2)	5.56 (6)	4.76 (6)	9.43 (13)
Hooghly	3.85 (5)	5.56 (5)	4.76 (5)	23.64 (11)
24Paraganas	2.78 (8)	2.13 (15)	1.92 (14)	-30.94 (15)
Nadia	2.70 (9)	4.76 (11)	3.70 (12)	37.04 (6)
Murshidabad	1.96 (14)	4.55 (12)	3.70 (13)	88.78 (3)
West Dinajpur	1.75 (15)	4.55 (13)	1.85 (15)	5.71 (14)
Malda	3.13 (7)	5.26 (8)	4.17 (8)	33.23 (7)
Jalpaiguri	2.63 (11)	4.76 (14)	3.85 (11)	46.39 (5)
Darjeeling	5.88 (1)	7.14 (1)	6.67 (1)	13.44 (12)
Cooch Behar	2.27 (13)	5.00 (9)	4.17 (9)	83.70 (4)
Purulia	3.23 (6)	5.00 (10)	4.17 (10)	29.10 (9)
W. B.	4.17	5.88	5.26	26.14
C-V	34.67	21.72	28.99	94.65
$Corr_{ij}$		R_{23} = 0.63	R_{24} = 0.75	R_{25} = -0.43
Top 5 Dists.	Darjeeling, Howrah, Birbhum, Burdwan, Hooghly	Darjeeling, Birbhum, Burdwan, Bankura, Hooghly	Darjeeling, Birbhum, Burdwan, Bankura, Hooghly	Midnapore, Bankura, Murshi- dabad, Cooch Behar, Jalpaiguri
Bottom 5 Dists.	Jalpaiguri, Midna- pore, Cooch Behar, Murshidabad, West Dinajpur	Nadia, Murshidabad West Dinajpur, Jalpaiguri, 24Paraganas	Jalpaiguri, Nadia, Murshidabad, 24Paraganas, West Dinajpur	Hooghly, Darjeeling, Howrah, West Dinajpur, 24Paraganas

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Table 13 : Crop Diversification Indices in West Bengal for Various Years between 1970-3 to 2002-5

	Herfindahl Index				Simpson Index			
0	1	2	3	4	5	6	7	8
District	**1970-73**	**1979-82**	**1989-92**	**2002-05**	**1970-73**	**1979-82**	**1989-92**	**2002-05**
Burdwan	.5278 (5)	.4839(7)	.4013(6)	.3734 (7)	.4722(11)	.5161(9)	.5987(10)	.6266 (9)
Birbhum	.4027 (8)	.5594(4)	.5014(3)	.4378 (3)	.5973 (8)	.4406(12)	.4986(13)	.5622(13)
Bankura	.6261 (2)	.6388(2)	.5171(2)	.4862 (2)	.3739(14)	.3612(14)	.4829(14)	.5138(14)
Midnapore	.5821 (4)	.6156(3)	.4811(5)	.4017 (5)	.4179(12)	.3844(13)	.5189(11)	.5983(11)
Howrah	.4515 (6)	.4915(6)	.3318(9)	.3841 (6)	.5485(10)	.5085(10)	.6682(7)	.6159(10)
Hooghly	.3119 (11)	.3277(8)	.2888(11)	.2771 (12)	.6881 (5)	.6723(7)	.7112(5)	.7229 (4)
24Paraganas	.5829 (3)	.5550(5)	.4836(4)	.4153 (4)	.4171(13)	.4450(11)	.5164(12)	.5847(12)
Nadia	.1666 (15)	.1642(15)	.1502(15)	.1476 (15)	.8334 (1)	.8358(1)	.8498(1)	.8524 (1)
Murshidabad	.1766 (14)	.1763(14)	.1772(14)	.1686 (14)	.8234 (2)	.8237(2)	.8228(2)	.8314 (2)
West Dinajpur	.3095 (12)	.2985(12)	.3711(8)	.2825 (11)	.6905 (4)	.7015(4)	.6289(8)	.7175 (5)
Malda	.1769 (13)	.1825(13)	.2194(13)	.2094 (13)	.8231 (3)	.8175(3)	.7806(3)	.7906 (3)
Jalpaiguri	.4160 (7)	.3557(9)	.3964(7)	.3654 (8)	.5840 (9)	.6443(8)	.6036(9)	.6346 (8)
Darjeeling	.3541 (9)	.3262(10)	.2838(12)	.3283 (10)	.6459 (7)	.6738(6)	.7162(4)	.6717 (6)
Cooch Behar	.3328 (10)	.3003(11)	.3255(10)	.3310 (9)	.6672 (6)	.6997(5)	.6745(6)	.6690 (7)
Purulia	.7035 (1)	.7665(1)	.6916(1)	.7791 (1)	.2965(15)	.2335(15)	.3084(15)	.2209(15)
W B	.3593	.3698	.3398	.2966	.6407	.6302	.6602	.7034
CV of Index	41.67	44.71	38.71	42.25	28.72	31.86	23.20	23.68
Rank Correlation	R_{12} = 0.943, R_{13} = 0.889, R_{14} =0.936, R_{23} = 0.925, R_{24} = 0.964, R_{34} = 0.954				R_{56} =0.943, R_{57} = 0.889, R_{58} = 0.936, R_{67} = 0.925, R_{68} = 0.964, R_{78} = 0.954			

Notes: (i) R_{ij} is the rank correlation between i^{th} and j^{th} column. All the correlation coefficients are significant at 1 per cent level of significance by two tailed test.

(ii) Figures in the parentheses represent ranking of the district.

Table 13: Concld

	Entropy Index				Modified Entropy Index			
0	1	2	3	4	5	6	7	8
District	**1970-73**	**1979-82**	**1989-92**	**2002-05**	**1970-73**	**1979-82**	**1989-92**	**2002-05**
Burdwan	1.1395(11)	1.2695(9)	1.3242(9)	1.3119(11)	-.4586(11)	-.5109(9)	-.5329(9)	-.5279(10)
Birbhum	1.3069(7)	1.0816(11)	1.1655(12)	1.2430(13)	-.5260(7)	-.4353(11)	-.4690(12)	-.5002(12)
Bankura	0.8743(14)	0.9120(14)	1.1478(14)	1.1848(15)	-.3518(14)	-.3670(14)	-.4619(13)	-.4768(14)
Midnapore	0.9935(13)	0.9507(13)	1.1811(11)	1.3143(10)	-.3998(13)	-.3826(13)	-.4753(11)	-.5289(9)
Howrah	1.2992(9)	1.1799(10)	1.1553(13)	1.2224(14)	-.5228(9)	-.4748(10)	-.4649(14)	-.4919(13)
Hooghly	1.5309(5)	1.5542(5)	1.5858(4)	1.5114(9)	-.6161(5)	-.6255(5)	-.6382(4)	-.6082(8)
24Paraganas	1.0154(12)	1.0692(12)	1.1865(10)	1.3094(12)	-.4086(12)	-.4303(12)	-.4775(10)	-.5269(11)
Nadia	1.9683(1)	1.9683(1)	2.0225(2)	2.0243(1)	-.7921(1)	-.7921(1)	-.8139(1)	-.8146(1)
Murshidabad	1.9409(3)	1.9641(2)	1.9503(3)	1.9523(2)	-.7811(3)	-.7904(2)	-.7848(3)	-.7857(2)
West Dinajpur	1.6066(4)	1.6506(4)	1.5021(6)	1.7509(4)	-.6465(4)	-.6642(4)	-.6045(6)	-.7046(4)
Malda	1.9494(2)	1.8897(3)	2.0180(1)	1.8444(3)	-.7845(2)	-.7605(3)	-.8121(2)	-.7423(3)
Jalpaiguri	1.2010(10)	1.4044(8)	1.3451(7)	1.6494(5)	-.4833(10)	-.5652(8)	-.5413(8)	-.6638(5)
Darjeeling	1.3007(8)	1.4416(7)	1.5226(5)	1.5735(7)	-.5235(8)	-.5801(7)	-.6127(5)	-.6332(6)
Cooch Behar	1.3903(6)	1.4957(6)	1.4874(8)	1.5570(8)	-.5595(6)	-.6019(6)	-.5986(7)	-.6266(7)
Purulia	0.7265(15)	0.5814(15)	0.7210(15)	0.5748(6)	-.2924(15)	-.2340(15)	-.2901(15)	-.2313(15)
W. B.	1.5503	1.5390	1.5947	1.6719	-.6239	-.6193	-.6418	-.6728
CV of Index	28.82	30.05	25.75	24.97	28.82	30.05	25.75	24.97
Rank Correlation	R_{12} =0.95, R_{13} = 0.871, R_{14} =0.821, R_{23} = 0.946, R_{24} = 0.914, R_{34} =0.932				R_{56} =0.95, R_{57} = 0.871, R_{58} = 0.821, R_{67} = 0.946, R_{68} = 0.914, R_{78} = 0.932			
Note: All the correlation coefficients are significant at 1 per cent level of significance by two tailed test.								

Table 13 a : Testing Co-integration of the districts of West Bengal in terms of growth of HI during 1970-73 to 2002-05

Method	Criteria	Coeff.	T-value	Adj. R^2	F-Stat.	Log-likelihood	AIC	Max-lag	Remark
Sty. of CV of Dists.	Level	-0.623	-4.061	0.686	12.79	-52.46	4.175	8	No Co-int.
	1st Diff.	-1.615	-3.10	0.878	30.996	-50.19	4.399	8	Co-integrated
AEG	Level	-1.128	-6.179	0.545	38.18	99.57	-6.10	8	Co-integrated
	1st Diff.	-2.872	-6.781	0.79	36.07	86.54	-5.70	8	Co-integrated

Notes: (1) Critical value at 1% level = -3.679, at 5% level = -2.96, at 10% level = -2.62

(2) Sty. Indicates stationarity, AEG indicates Augmented Engle-Granger test.

Table 14 : Regression *Coefficients* of Percentage Growth of Proportion of GCA under *Boro Paddy* on Explanatory Variables with Varied Specifications (n = 15)

	Dependent Variable: Ln Δboro (Log-log Model)	Dependent Variable: Ln Δboro (Excluding Some Explanatory Variables)	Dependent Variable: Δboro (Line-log Model)
Explanatory Variables	R^2 = .847, Adj.R^2 = .643, F = 4.15	R^2 = .765, Adj. R^2 = .671, F = 8.15	R^2 = .963, Adj.R^2 = .896, F = 14.34
Constant	-1.857	-1.872***	-216.040*
Ln Δfertiliser	.036	.528	-.524
Ln Δmarket	.261	---	---
Ln Δstore	.252*	.271*	13.946*
Ln Δsf	.629**	.875*	20.761*
Ln Δepump	-.194	---	7.582*
Ln ΔAL	.380	---	41.285
Ln ΔminorIrri	.478**	.515*	2.883
LnΔ roadacity	.171	---	5.234
Ln Δcanalirri	---	---	16.157
Ln Δtractill	---	---	-3.01

Notes: (1) Here fertiliser indicates consumption of chemical fertiliser per hectare of GCA in the district, market = number of market per thousand Sq. Km., store = number of storage per thousand Sq. Km., sf = percentage of GCA under small and marginal farm, epump= number of electric pump set per hectare of GCA, AL=agricultural labourer as percentage of total working force, minorIrri= number of minor irrigation set up, roadacity= road density per thousand Sq. Km., tractill= total number of tractor and power tiller per hectare of GCA, canalirri= percentage of GCA under canal irrigation. HereΔ indicates percentage change of the variable during the whole period.

(2) *, ** and *** indicate that the coefficient is significant at five, ten and twenty per cent level of significance by two tailed test.

Table 15 : Regression Coefficients of log of Percentage Growth of Proportion of GCA under *Potato* and *Mustard,* (n = 15)

	Dependent Variable: Ln ΔPotato	Dependent Variable: Ln ΔMustard
Explanatory Var.	R^2 = .818, Adj. R^2 = .491, F = 2.50	R^2 = .830, Adj. R^2 = .702, F = 6.51
Constant	-5.208*	4.759*
Ln Δfertiliser	.810**	-.655**
Ln Δmarket	-.388*	.268**
Ln Δstore	.214*	.073***
Ln Δsf	.487*	.136
Ln Δepump	.102	---
Ln ΔAL	.170	---
Ln ΔminorIrri	.208***	-.275*
LnΔroadacity	-.263	.362**
Ln Δtractill	.178	.160
Note: Same as table-14.		

Appendix Table 1 : District-wise Percentage of Agricultural Labourer to total working force in Wes Bengal since 1971

District	1971	1981	1991	2001
Burdwan	4.90 (8)	28.16 (6)	29.76 (5)	29.88 (7)
Birbhum	16.15 (1)	35.42 (1)	34.32 (1)	36.95 (2)
Bankura	9.45 (4)	30.72 (5)	30.8 (4)	35.18 (4)
Midnapore	12.78 (2)	27.90 (8)	21.96 (11)	31.66 (5)
Howrah	2.60 (13)	14.25 (14)	14.49 (14)	10.13 (15)
Hooghly	3.66 (10)	26.90 (9)	26.13 (8)	24.29 (10)
24Paraganas	3.16 (11)	16.19 (12)	22.5 (10)	18.87 (12)
Nadia	6.41 (7)	27.92 (7)	26.98 (7)	23.21 (11)
Murshidabad	11.23 (3)	31.57 (3)	27.93 (6)	27.99 (9)
West Dinajpur	8.64 (5)	32.13 (2)	33.44 (2)	38.30 (1)
Malda	2.85 (12)	30.90 (4)	31.59 (3)	30.68 (6)
Jalpaiguri	3.76 (9)	15.39 (13)	15.8 (13)	17.64 (13)
Darjeeling	1.51 (15)	8.65 (15)	11.64 (15)	10.21 (14)
Cooch Behar	1.59 (14)	26.50 (10)	24.76 (9)	29.50 (8)
Purulia	8.57 (6)	20.13 (11)	20.86 (12)	36.09 (3)
W. B.	3.02	23.64	23.07	24.92
Top 5 Districts	Birbhum, Midnapore, Murshidabad, Bankura, WestDinajpur	Birbhum, WestDinajpur, Murshidabad, Malda, Bankura	Birbhum, WestDinajpur, Malda, Bankura, Burdwan	WestDinajpur, Birbhum, Purulia, Bankura, Midnapore
Bottom 5 Districts	24Paraganas, Malda, Howrah, CoochBehar, Darjeeling	Purulia, 24Paraganas, Jalpaiguri, Howrah, Darjeeling	Midnapore, Purulia, Jalpaiguri, Howrah, Darjeeling	Nadia, 24Paraganas, Jalpaiguri, Darjeeling, Howrah

Appendix Table 2 : Number of Villages Electrified in West Bengal (District-wise)

District	1973	1989	1994	2000	Rate of Growth during 1973-2000
Burdwan	830 (1)	2143 (3)	2411 (3)	2441 (4)	194.10 (13)
Birbhum	272 (8)	2191 (4)	2213 (6)	2213 (6)	713.60 (4)
Bankura	320 (7)	1596 (7)	2304 (5)	2412 (5)	653.75 (6)
Midnapore	706 (3)	3859 (1)	5166 (1)	5567 (1)	688.53 (5)
Howrah	244 (10)	694 (13)	755 (13)	755 (13)	209.43 (11)
Hooghly	644 (4)	1743 (6)	1898 (7)	1898 (7)	194.72 (12)
24Paraganas	823 (2)	2859 (2)	3218 (2)	3314 (2)	302.67 (9)
Nadia	612 (5)	1242 (10)	1254 (10)	1254 (10)	104.90 (15)
Murshidabad	454 (6)	1561 (9)	1781 (8)	1794 (8)	295.15 (10)
West Dinajpur	85 (14)	2099 (5)	2377 (4)	2496 (3)	2836.47 (1)
Malda	245 (9)	1587 (8)	1596 (9)	1596 (9)	551.43 (7)
Jalpaiguri	178 (12)	694 (14)	725 (14)	725 (14)	307.30 (8)
Darjeeling	190 (11)	434 (15)	510 (15)	524 (15)	175.79 (14)
Cooch Behar	71 (15)	1082 (11)	1118 (12)	1118 (12)	1474.65 (2)
Purulia	158 (13)	1075 (12)	1480 (11)	1567 (11)	891.77 (3)
W. B.	5832	24858	28806	29574	407.10
Top 5 Dists.	Burdwan, 24Paraganas, Midnapore, Hooghly, Nadia	Midnapore, 24Paraganas, Burdwan, Birbhum, WestDinajpur	Midnapore, 24Paraganas, Burdwan, WestDinajpur, Bankura	Midnapore, 24Paraganas, West Dinajpur, Burdwan, Bankura	West Dinajpur, CoochBehar, Purulia, Birbhum, Midnapore
Bottom 5 Dists.	Darjeeling, Jalpaiguri, Purulia, WestDinajpur, CoochBehar	CoochBehar, Purulia, Howrah, Jalpaiguri, Darjeeling	Purulia, CoochBehar, Howrah, Jalpaiguri, Darjeeling	Purulia, CoochBehar, Howrah, Jalpaiguri, Darjeeling	Howrah, Hooghly, Burdwan, Darjeeling, Nadia

Appendix Table 3 : District-wise Area under Small Farms and its Growth during 1969-70 to 2001-02

	Area in Hectare				Percentage Growth	Percentage of Total Agricultural Farm Area			
District	1969-70	1990-91	1995-96	2001-02	1969-70 to 2001-02	1969-70	1990-91	1995-96	2001-02
Burdwan	263790.83	271859	313517	341507	29.46 (8)	64.37 (10)	58.75 (11)	66.39 (11)	72.33 (12)
Birbhum	165859.26	173730	217978	225265	35.82 (6)	59.19 (12)	57.66 (12)	70.41 (8)	73.51 (10)
Bankura	231635.13	253377	251222	256509	10.74 (14)	66.02 (9)	65.42 (8)	64.64 (13)	65.99 (13)
Midnapore	612871.04	676856	714163	750136	22.40 (9)	75.28 (4)	79.72 (2)	86.11 (2)	91.06 (2)
Howrah	84774.368	90686	93128	95166	12.26 (13)	92.05 (1)	87.27 (1)	88.62 (1)	88.18 (4)
Hooghly	163507.56	179866	177513	187247	14.52 (12)	78.98 (2)	77.12 (3)	80.83 (4)	86.01 (5)
24Paraganas	489469.04	521376	507712	581064	18.71 (10)	73.88 (5)	73.59 (4)	76.70 (6)	88.88 (3)
Nadia	183173.9	233356	289535	1486081	711.30 (1)	66.37 (8)	65.68 (6)	81.24 (3)	97.32 (1)
Murshidabad	249909.2	231687	340200	356322	42.58 (4)	71.46 (6)	54.11 (13)	77.01 (5)	81.15 (7)
WestDinajpur	221331.46	294471	316803	356199	60.93 (2)	53.49 (13)	64.52 (9)	69.79 (9)	79.31 (8)
Malda	161193.18	202720	205804	251874	56.26 (3)	63.68 (11)	67.00 (5)	68.19 (10)	84.28 (6)
Jalpaiguri	150028.95	144812	169100	195799	30.51 (7)	46.01 (14)	42.00 (14)	47.42 (14)	55.14 (14)
Darjeeling	51741.272	49941	60134	59285	14.58 (11)	32.27 (15)	31.67 (15)	38.81 (15)	38.91 (15)
CoochBehar	148301.2	176930	181733	208214	40.40 (5)	76.98 (3)	65.53 (7)	65.86 (12)	75.80 (9)
Purulia	182830.44	176261	184255	189861	3.85 (15)	66.89 (7)	59.82 (10)	70.78 (7)	72.94 (11)
W. B.	3360416.8	3677928	4022797	4365529	29.91	66.39	65.03	71.99	78.71
Top 5 Dists.					Nadia, Westdinajpur, Malda, Murshidabad, CoochBehar	Howrah, Hooghly, CoochBehar, Midnapore, 24Paraganas	Howrah, Midnapore, Hooghly, 24Paraganas Malda	Howrah, Midnapore, Nadia, Hooghly, Murshidabad	Nadia, Midnapore, 24Paraganas Howrah, Hooghly
Bottom 5 Dists.					Darjeeling, Hooghly, Howrah, Bankura, Purulia	Malda, Birbhum, WestDinajpur, Jalpaiguri, Darjeeling	Burdwan, Birbhum, Murshidabad, Jalpaiguri, Darjeeling	Burdwan, CoochBehar, Bankura, Jalpaiguri, Darjeeling	Purulia, Burdwan, Bankura, Jalpaiguri, Darjeeling

Appendix Table 4 : District-wise Area under Large Farms and its Growth during 1969-70 to 2001-02

	Area in Hectare				Percenta geGrowth	Percentage of Total Agricultural Farm Area			
District	1969-70	1990-91	1995-96	2001-02	1969-70 to 2001-02	1969-70	1990-91	1995-96	2001-02
Burdwan	409.80	2783	3121	992	142.07	0.1 (13)	0.60 (3)	0.66 (4)	0.21 (7)
Birbhum	2185.68	1133	1359	707	-67.65	0.78 (3)	0.38 (8)	0.44 (5)	0.23 (6)
Bankura	561.37	494	745	304	-45.85	0.16 (10)	0.13 (13)	0.19 (11)	0.08 (12)
Midnapore	2930.84	1483	2253	900	-69.29	0.36 (4)	0.17 (12)	0.27 (10)	0.11 (9)
Howrah	110.52	262	185	393	255.59	0.12 (11)	0.25 (10)	0.18 (12)	0.36 (4)
Hooghly	310.54	72	166	304	-2.11	0.15 (9)	0.03 (15)	0.08 (15)	0.14 (8)
24Paraganas	530.02	509	671	246	-53.59	0.08 (14)	0.07 (14)	0.10 (14)	0.04 (14)
Nadia	717.57	1530	1035	870	21.24	0.26 (8)	0.43 (6)	0.29 (9)	0.06 (13)
Murshidabad	1084.13	993	773	158	-85.43	0.31 (6)	0.23 (11)	0.17 (13)	0.04 (15)
WestDinajpur	496.54	1769	1461	5257	958.73	0.12 (12)	0.39 (7)	0.32 (8)	1.17 (3)
Malda	582.20	1625	1116	324	-44.35	0.23 (7)	0.54 (4)	0.37 (6)	0.11 (10)
Jalpaiguri	119931.86	121236	120833	124745	4.01	36.78 (2)	35.16 (2)	33.88 (2)	35.13 (2)
Darjeeling	65489.90	66537	65809	82829	26.48	40.85 (1)	42.20 (1)	42.48 (1)	54.36 (1)
CoochBehar	0.00	1402	2206	259	-81.53*	0 (15)	0.52 (5)	0.80 (3)	0.09 (11)
Purulia	847.32	840	822	688	-18.80	0.31 (5)	0.29 (9)	0.32 (7)	0.26 (5)
W. B.	195885.12	202668	202555	218976	11.79	3.87	3.58	3.62	3.95
Top 5 Dists.						Darjeeling, Jalpaiguri, Birbhum, Midnapore, Purulia	Darjeeling, Jalpaiguri, Burdwan, Malda, CoochBehar	Darjeeling, Jalpaiguri, CoochBehar, Burdwan, Birbhum	Darjeeling, Jalpaiguri, WestDinajpur, Howrah, Purulia
Bottom 5 Dists.						Howrah, WestDinajpur, Burdwan, 24Paraganas CoochBehar	Murshidabad, Midnapore, Bankura, 24Paraganas, Hooghly	Bankura, Howrah, Murshidabad 24Paraganas, Hooghly,	CoochBehar, Bankura, Nadia, 24Paraganas, Murshidabad

Note: *Growth from 1991 to 2001 in case of Cooch Behar

Global Journal of Science Frontier Research (D) Volume XIII Issue V Version I Year 2013

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Global Journal of Science Frontier Research
Agriculture and Veterinary
Volume 13 Issue 5 Version 1.0 Year 2013
Type : Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 2249-4626 & Print ISSN: 0975-5896

Farmer's Land Mapping: A Public Policy Document to Solve Local Problems

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Abstract - The farmer's land map can be considered an instrument of public policy to solve specific problems, since local populations have a detailed knowledge of their lands. Such knowledge can be systematized using the procedure known as land cartography, the method for which implies considering the social structure of the towns, and the result is that the geographic knowledge stored in the minds of the informantsis turned into maps, graphs or written documents that can be used to carry out an analysis of the communal territory, with the possibility of driving actionsin terms of public policy. From this viewpoint, participation of the locals is necessary to solve social inequalities and economic and environmental imbalances.

GJSFR-D Classification : FOR Code: 070106

FARMERS LAND MAPPINGA PUBLIC POLICY DOCUMENT TO SOLVE LOCAL PROBLEMS

Strictly as per the compliance and regulations of :

Farmer's Land Mapping: A Public Policy Document to Solve Local Problems

David Pájaro Huertas [α] & Enriqueta Tello García [σ]

Summary - The farmer's land map can be considered an instrument of public policy to solve specific problems, since local populations have a detailed knowledge of their lands. Such knowledge can be systematized using the procedure known as land cartography, the method for which implies considering the social structure of the towns, and the result is that the geographic knowledge stored in the minds of the informantsis turned into maps, graphs or written documents that can be used to carry out an analysis of the communal territory, with the possibility of driving actionsin terms of public policy. From this viewpoint, participation of the locals is necessary to solve social inequalities and economic and environmental imbalances.

I. Background

For the past decade, planning for national, regional and local development has been based on the promotion of megaprojects and strategic plans that have been justified by the processes of globalization and the competitive insertion of the regions in the international system, regardless of the negative effects caused. Such is the case of the farming towns, *ejidos*, and the indigenous peoples of Mexico, which are constantly preyed upon by the government agents at the service of Mexican and foreign investors, who incessantly intend to take control of their lands and natural assets: the*sierras*, the water, the underground, the plants, animals and their genes, culture, ancient knowledge and the forms of social organization and rural politics (Barrera *et al*, 2012), and are unfortunately supported by a whole legal political framework that legitimates the plundering of such resources in the insatiable search for more profit. We can take for granted that these forms of planning ("from the top") create a series of problems between diverse actors, which lead to intense conflicts. A greater participation of the civil society therefore becomes necessary, in order to create a plan of action collectively, in which every one feels identified and committed to take action. A commitment by the central administration is also important if the participation of citizens is to be effective (and is not reduced to a few groups or associations), as well as the proposals made are carried out with the intervention and follow-up of the population (Garrido, 2002).

II. Political Territorial Context

In Mexico, in the insatiable search for the highest possible profit, public policies have been driven with the purpose of guaranteeing the continuity of a dominant system that perpetuates the hierarchy, exploitation, and polarization. This has lead to millions of Mexican farmers, craftspeople, small and medium shopkeepers, along with other sectors of small businesspeople into bankruptcy (Serrano, 2007). And despite the different social, economic, and political pressures to exploit their natural resources and their populations, rural communities have survived and are determined to reproduce their culture, they are aware of the situation they live in, and are committed to defending their territories and they know that in order to confront the dominant economic model "*cultural identity, ancient and upcoming epistemologies, the voice of the elderly, community work, the adequate use of natural assets, autonomous education, assemblies, reciprocity and community, as well as the capacity to have dialogues with other authors; these must all must be proposed from their inner forces*" (Cuellar *et al*, 2013 and Barrera *et al*, 2012). When considering these proposals that arise as small actions, and when everybody, from their action and ideological trench, formulates an alternative solution that can counteract the negative effects of the dominating model, the result will be the construction of a new model proposed by social actors that live and know concrete spaces from infinitenanoscopic actions, (Wallerstein, 2013). We would be faced with another way of doing politics, in which common people could decide and execute; Wallerstain (2013) claims that it is necessary to create forms of power different to those used by the State in order to guarantee territorial autonomy, in which it is crucial to ensure material sovereignty (health, education, housing and food) by re-appropriating the territory, collectively, to resist adversities and protect life. "*If we want to fight for a better world, the defense of our territory is essential*" (Zibechi, 2013).

III. Proposal

One's territory is where one dreams and feels, where awareness is raised, where myths and ritual life are recreated giving a meaning to community life (Barrera *et al*, 2012). Bringing up proposals of action from the territory is creating spaces in which one can guarantee local life in all its multifaceted dimensions, as well as generating resistance nuclei from the social relations that are weaved around the values of use and reciprocity to neutralize government policies that intend to destroy what is collective (Zibechi, 2013). From this perspective, we propose the use of the farmer's land map as a document that blends the native knowledge on soils and the expectations of a solution to the problems of each *ejido* or community, because: 1) it contributes to the reappropiation of the territory, empowering farmers, and can therefore be considered a political instrument; 2) it considers the farmer's context, his/her cultural surroundings and the ejido's or the communal territory; 3) it represents the interests of the locals, and 4) the land map has a local cultural meaning that reproduces the social surroundings of the communities (Pájaro, 2010; Tello *et al.*, 2011;Pájaro and Tello, 2012). This makes the farmer's land map a cultural and a social document, since it is a document with which the social order is communicated, reproduced, experienced and explored, and can therefore be used as an instrument of power (Harley, 1988), with almost unlimited repercussions in different domains of knowledge.

a) Epistemology of farmer's land maps

An alternative method to soil surveys and agrological studies has been called “land mapping” (Ortiz Solorio et al., 1990) or “participatory mapping” (Pájaro Huertas & Tello García, 2012). Here, the result again is a soil distribution map in the area under study, accompanied by textual information on distinctive characteristics of relevant soil types and recommend-dations for soil management – always from the farmers' point of view. Participatory mapping is a methodological tool. It takes into account social structures of concerned communities and helps to visualize farmers' cognitive maps in the form of (carto) graphic maps. Hence, respecting the locals' self-recognition and self-representation helps strengthening the participation of communities in search of alternatives and solutions for problems within the communal territory (cf. fig. 1). The methodology of land mapping or participative mapping is based on the simple fact that local populations have a detailed knowledge on their lands and resources, and that this knowledge can be gathered and interpreted geo- and cartographically. Essentially, this methodology combines participatory research with spatial-environmental knowledge, cognitive comprehension and mapping techniques. As a result, cartographic knowledge stored in the locals' minds becomes visible and communicable in the form of maps, graphs or written documents. These documents then can be used to analyze the land with the possibility of boosting action in terms of public policies (figure 1).

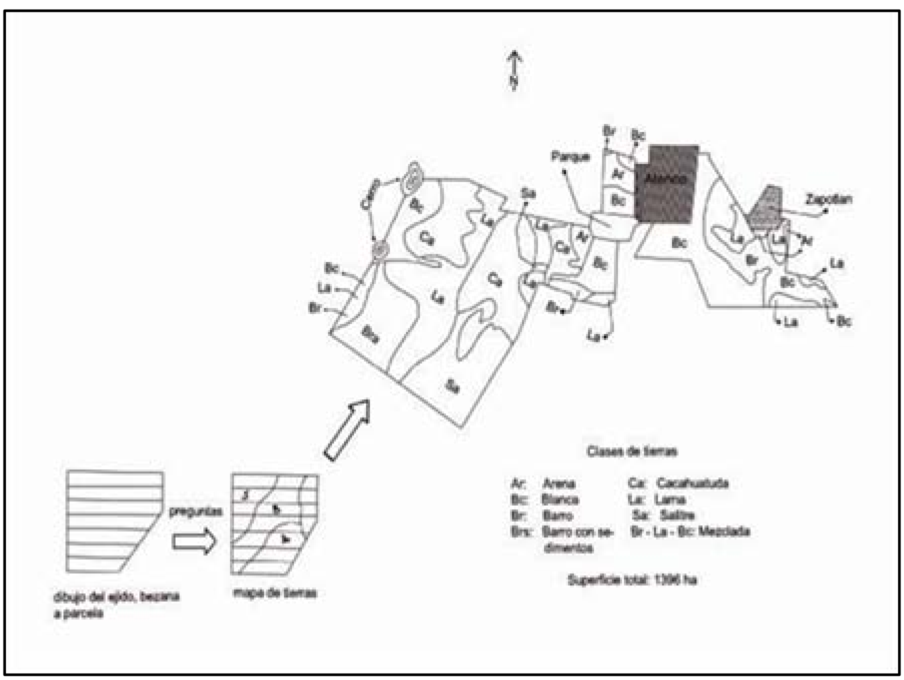

Figure 1 : Cartography of lands (after Pájaro y Ortiz, 1987 y Ortiz et al., 1990)

The studies we realized do not only include the owners of the ejidos (Pájaro, 2011), but also local authorities (the ejido's commissioner), as well as other groups organized inside each community. Identifying and including the different actors involved in land use may help to find strategic alliances in order to propose and solve the issues highlighted by each land map. The idea is to position the map in the mental domain of the local community, but as well of everyone who interacts in the territory, as a public policy instrument that helps:

1. Criticize the results obtained, whether by informants or by the community in general
2. Reaffirm or correct the objectivity of the information obtained

3. Create an interest in the problems in the ejido within the community
4. Obtain a consensus to begin some action plan for the solution of that problem, and
5. Show that the land map is a tangible object, because it shapes the native knowledge on soils, it promotes actions by farmers, and consequently, its political dimension is exposed.

The methodological proposal helps zonify at a level of plots within each ejido, where farmer participation, in order to identify different soil types, but also to know their problems, is decisive, and also systematizes the possible solutions to the problem that each ejido faces. Therefore, institutional tutelage is avoided and farmers are recognized as mature individuals and active members of their community, capable to contribute to solving the problems that may arise.

The different problems identified and the solutions presented by interested locals, enable municipal authorities and consultative councils to define priorities and actions under an ethical and realistic perspective, based on the resources available. Likewise, participatory agreements can be made with other institutions in order to solve the problems presented by the farmers, which would allow to switch the decision-making process from a “deciding for” mode to “deciding with” or “enabling deciding by” modes.

b) The political perspective of land maps

The implicit discourse of land maps must be analyzed in its political and social dimension to understand how it intervenes and how it acts. For this purpose it is necessary:

1. To position farmers' knowledge of soil in the context of society;
2. To acknowledge that maps are forms of visual language to communicate both territorial and property rights in symbolic and practical ways;
3. To recognizes that the detailed map categories favor a political and social discourse, which gives privileges to certain types of truths
4. And to communicate the problems regarding land and land use

As shown before, the land map is a geographical reference serving as a starting point when actions in the common lands have to be taken. Subsequently, two contrasting examples shall demonstrate the advantages of participatory mapping. Ignoring these advantages may cause other problems, even beyond a local scale level and upset the regional and national political environment.

i. The defense of communal lands

The latest social movements in and around the Eastern part of the State of Mexico (Estado de Mexico), specifically those that concern people of Atenco (Pájaro Huertas, 2002, 2006) and towns in Texcoco (San NicolásTlaminca, Huexotla and Tequexquinahuac) near the mine shafts, where toxic waste from Mexico City is currently being deposited teach interesting lessons, for example in regard of organization, resistance, social solidarity, forms of struggle and leadership.

A common element defines all of these movements: they are collective entities, i.e. a political subject, with the power of communitarian decision-making and of direct negotiation with well-defined cultural and territorial roots (Esteva, 1985). Its forms of organization and participation with communication networks between participating towns and communities make us focus in further detail on the collective subject and on the common territory.

It is also true that it is always the community that argues, makes decisions and gives orders to carry them out. However, the key of their success lies in the peculiar relationship of the leaders with their bases, because without their support, they would never have achieved what they did, e.g. stopping the questionable project of a new airport in Mexico City (in Atenco) and the deposit of toxic waste (in Texcoco). They reflect the dialectical interplay of hegemonies and counter-hegemonies of the historical blocks, now inserted in a worldwide neoliberal context, when the peoples are taking initiative and start to transform their reality, according to their interests.

We can claim that, since the topic is much more complicated than it seems, and more that we have mentioned here, the “small” people's resistance movements and their modest natural leaderships, are, nowadays, the best track of analysis for those who search and are concerned for the liberation of humans, keeping in mind that these struggles take place in defense of common territories. A brutal clash of two discourses in a context of “real- politics.” The hyper realistic conflict of people from Atenco and Texcoco, who defend their modest heritage, their lifestyle, traditions, history, their dead, their dignity, myths, rites, beliefs, festivities, their traditional clothing, their laughter, animals and homes, has an objective reference: the common territory and, consequently, the land map. Because everyday activities are carried out in those small environments, for the inhabitants of these small towns and their ways of organization and making decisions, any action not approved by them can be fatal, since it would affect the best lands or the common peace and quiet.

ii. The change of land use

On the other hand, from a technical viewpoint, a growing problem in the State of Mexico is the disorderly growth of urban settlements, for example in 14 municipalities of the Texcoco region, covering a large area of ca. 260000 hectares from Ecatzingo (adjacent to the state of Morelos) to Coacalco and Ecatepec in the north of Mexico City. 70000 hectares of this area are occupied by urban settlements – equivalent to a city of 70 km in lengths by 10 km in width. Despite ongoing urbanization, 353 deep wells are used in this area for agricultural irrigation purposes, which, organized adequately, would inform several other irrigation units for rural development (Unidades de riego para el desarrollo rural (URDERALES)).

The governing plan for agricultural and forestry development of the mitigation area in the municipalities of Atenco, Texcoco and Tezoyuca (Comisión Nacio-naldel Agua, 2009), mentions 60 deep wells for agricultural irrigation. However, only 47 of them are functioning, and in many cases just inefficiently and energy wasting due to outdated pumping equipment with an electro-mechanical efficiency of, at best, 50 %. Furthermore, it is worth noting that only 20% of all irrigation channels are lagged, causing leaks and waste of water from the well to the point of use. Along with this, we must include the fact that the farmers from the Atenco-Texcoco-Tezoyuca region are just beginning to learn about technified irrigation systems, which would help them save considerable volumes of water in each well (Instituto de Ingeniería Agrícola y Uso Integral del Agua, 2010).

If the 47 wells for agricultural irrigation in the Atenco-Texcoco-Tezoyuca region were conformed into URDERALES, 5,000 hectares could be irrigated, where currently a large variety of basic, fodder and vegetable crops is being produced; this would mean both better incomes for the farmers of this region and more jobs for laborers due to the demand for technical assistance, options for agricultural credits, and the need for storage and selling the products. In consequence, these 5,000 hectares - located on flat grounds that usually show high soil quality, and of which currently less than 1,000 hectares are irrigated – would become part of the agricultural production and would, therefore, no longer be a point of attraction for uncontrolled urban settlements.

In this situation, the new government administration with its three levels (municipal, state, and federal), which will soon become consolidated, must pay particular attention to the problem of change of land use in the Texcoco region. If crop fails frequently due to bad soil and infrastructure management, farmers may tend to sell their land for the construction of houses, malls, industrial parks or any other non-agricultural use; this would imply a series of problems common to these municipal areas.

To consolidated irrigation units for rural development, just little financial input would be necessary, since most of the legislation for their setup and support already exists; what is needed is a good work, initiative and creativity component to help this reach the farmer's field, simply because they have the best lands and most of the infrastructure for this purpose. The land maps for the ejidos studied shows this.

The farmers, technicians, administrators, politicians, and governors, as human beings, are intelligent beings, and if we have more than one situation we can think about the event and take the better alternative for our future. According to the experiences in Atenco and Texcoco, farmers opted for defending their common territory and for the formation of irrigation units, to name just two concrete examples. However, if no action is taken, more and more farmers will sell their plots.

Finally, as we have been explaining with examples, land maps, through the defense of one's territory and the integration of irrigation units for rural development, are a form of participation and of individual and collective exercise that legitimizes the rights of farmers and the community of taking influence on local, national and international policies.

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Global Journal of Science Frontier Research
Agriculture and Veterinary
Volume 13 Issue 5 Version 1.0 Year 2013
Type : Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 2249-4626 & Print ISSN: 0975-5896

Histopathologic Biomarker of Fish Liver as Good Bioindicator of Water Pollution in Sitnica River, Kosovo

By Morina Valon, Aliko Valbona, Eldores Sula, Gavazaj Fahri, Kastrati Dhurata & Cakaj Fatmir

University of Prishtina

Abstract - The histostructure of fish liver from Sitnica river was studied in order to detect the effects of pollution of Sitnica River in Kosovo.Fish (n=21) were sampled during March-May and August-September of 2010-2012 from sites Ferizaj, Vragoli and Plemetin (Sitnica River). The morphological alterations in the liver were mainly more degenerative in fish from Vragoli and Plementin polluted sites than Ferizaj one. Ferizaj is source of the river site, so it is less contaminated than the two other sites. Fish liver histopathology is a good bioindicator and can be used for detection of chemical pollution in fish. Based on results of our research we can conclude that “Sitnica” River is polluted river mainly by industrial and urban discharge of liquid waste products.

Keywords : freshwater fish, liver, histopathology, sitnica river, pollution.

GJSFR-D Classification : FOR Code: 300799p

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Morina Valon [α], Aliko Valbona [σ], Eldores Sula [ρ], Gavazaj Fahri [Ѡ], Kastrati Dhurata [¥] & Cakaj Fatmir [§]

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Keywords : freshwater fish, liver, histopathology, sitnica river, pollution.

I. Introduction

In recent years, the anthropogenic pollution of aquatic ecosystems increased the need for studies to identify the impact of heavy metals on the species living there. Fish are often exposed to highly polluted water, and that causes different disabilities, ranging from biochemical changes in single cells to changes in the whole organism. Monitoring programs for measuring the accumulation of heavy metals in fish tissues serve as a biomarker of water pollution and provides information about the environmental conditions.

Histological changes are more sensitive and occur earlier. They provide a better assessment of fish health, as well as the effects of pollution on each biochemical parameter. Histopathological changes have been integrated with the impact of various stressors (microbial pathogens, toxic compounds, nutritional and adverse environ-mental conditions (Marchand et al., 2009).

Recently the Sitnica River is converted into a natural recipient of waste waters like the ones coming from Kosovo power plants in Obiliq, and waters from bigger and smaller central urban canalization systems, through which river flows down, and because there are unresolved problems of treatment and purification of discharged waters. Experimental results have shown that quality of Sitnica River water is endangered from heavy metals (Pb, Cd, Cu, and Zn) and phenols. Anomalous values of Cu, Cd, Pb and Zn, far exceeded the allowed values of the fourth category of the quality of surfaced waters, causing significant toxic effects in sediments at Mitrovica location (about 50 km upstream from the border of Serbia).(Bilinski et.al 2010). In our previous study (Morina et al., 2013) we found that the activity of AST and ALT enzymes in fish collected in Sitnica River were significantly increased. AST exhibited a higher increase than ALT. ALT is a key metabolic enzyme released on the damage of hepatocytes. The purpose of this study was to evaluate the influence of anthropogenic water pollution of Sitnica River on the liver histostructure of the fish species.

II. Materials and Methods

a) *Study areas and collection of specimens*

Three site (1, 2, 3) were chosen for active biomonitoring and investigation of water pollution in Sitnica River.

b) *Animals*

Fish species (in total 21 fish individuals) were collected with electrofishing method from three sites along Sitnica River sources of river {site1-Ferizaj (C.carassius,n=8)}, {site 2-Vragoli (G.obstrusirostris, n=5)} and {site 3- Plemetin (C.carassius, n=8)} during the period March-May and August-September of 2010-2012. The animals were transported to the laboratory in the containers with constant aeration.

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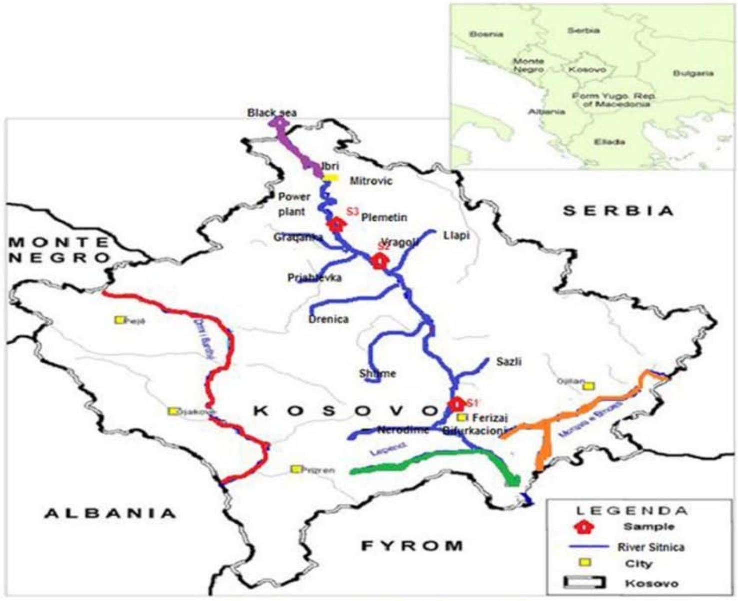

Figure 1. Study area with sampling stations

c) Histopathological Analysis

From each individual liver tissues were collected putting them into bottles with 10 % formaline solution. Tissue samples for histological examination were taken from livers of normal and polluted fish. For light microscopy, samples were first weighted, fixed in 10% buffered formalin for twenty-four hours at 4ºC and then immediately dehydrated in graded series of ethanol, immersed in xylol, and embedded in paraffin wax using an automatic processor. Sections of 3–5 μm were mounted. After they had been deparaf-finized, the sections were rehydrated, stained with hematoxylin and eosin, and mounted with Cristal/Mount. Evaluation of slides and photo-graphing were done with optic microscope (Zeiss, X100). Qualitative and quantitative evaluation of liver tissue histology included tissue transparency, cell vitality and nucleus/cytoplasmic nucleus size ratio.

III. Results & Discussions

Liver is the largest and important organ of the body doing several physiological functions. It has no direct contact with pollutants dissolved in water. The histology of fish liver from the river source and polluted sites is shown in Figures 2, 3, 4, 5 and 6. The liver of the fish from river sources (site1-Ferizaj) exhibited a normal architecture and there were no pathological abnorm-alities, with hepatocytes prese-nting a homogenous cytoplasm, and a large central or subcentral spherical nucleus (Fig.2). Nuclear karyolysis and karyopiknosis, are observed in different regions of fish liver from polluted site 2-Vragolia. (Fig.3). Karyolysis is the complete dissolution of the chromatin matter of a dying cell, Pyknosis, or karyopiknosis, is the irreversible condensation of chromatin in the nucleus of a cell undergoing necrosis or apoptosis. This indicates that the fish are under a highly stressful condition due to the presence of industrial effluents. These results are in agreement with findings of Dhevakrishnan, R and M.H. Zaman, (2012); Ebrahimi, M, Taherianfard, M (2011).

Hydropic vacuolation (HydVac) were observed in fish from polluted site 2-Vragolia (Fig 4). Stehr CM et al, (1998) have reported that risk for HydVac increased with the presence of aromatic and chlorinated hydrocarbons in sediment, fish bile, and fish liver. Inflammation with lymphocytes of portal areas were observed in fish liver from polluted site 3-Plemetin (Fig.5). Our findings are supported by the fact that Plementin sampling site was reported to have the highest level of heavy metals. Our result are according the result of Bothaina m.Khidr et al 2012, study which deals with the histological changes of the hepatocytes of the *Nile tilapia*, *Oreochromis niloticus*, following exposure to 2.5, 5, 10 ppm of lead nitrate for 1, 2, 3, 4 weeks. Our results revealed that lead nitrate exerts some histological effects on the hepatic tissue. During examination of liver sections of fish from polluted site 3-Plemetin (Fig.6) we observed lytic necrosis areas. These results are in agreement with findings of S. V. Deore and S.B Wagh (2012), who reported that histopathological impact of lethal and sublethal concentrations of mercury chloride and copper chloride in liver of fresh water teleost, *Channa gachua* (Ham) revealed vacuolation in cytoplasm, degeneration of nuclei, vacuolation in stroma, cloudy swellings, pycnotic nuclei, necrosis, rupture of blood sinusoids, disarray of hepatic cords, loss of shape of hepatocytes. The toxicity effect of heavy metals and other pollutants on liver have been studied by many researchers.Velcheva et al (2010) reported necrotic and hyperemic changes in the parenchyma of liver due to heavy metals pollution. Mohammad M.N. Authman et al (2013) reported, the histopathological changes in the liver of *C. gariepinus* fish, collected from El- Rahawy drain, include loss of cellular architecture of liver, vacuolar degeneration, pycnotic nuclei and focal areas of necrosis of the hepatocytes. Leukocyte infiltration and hyaline degeneration were also detected in the hepatic tissues of fish. Dilation of the central vein accompanied by blood congestion was detected due to heavy metals pollution.

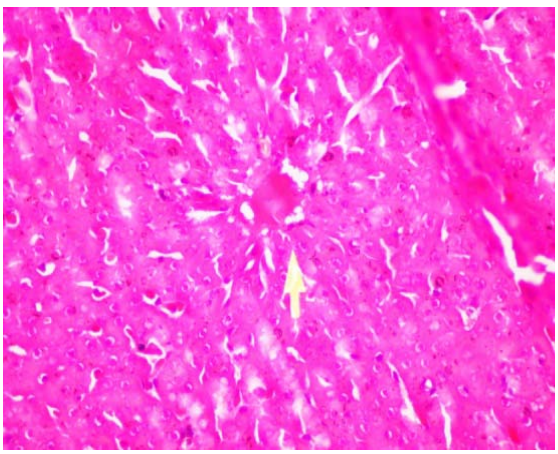

Figure 2 : Control group

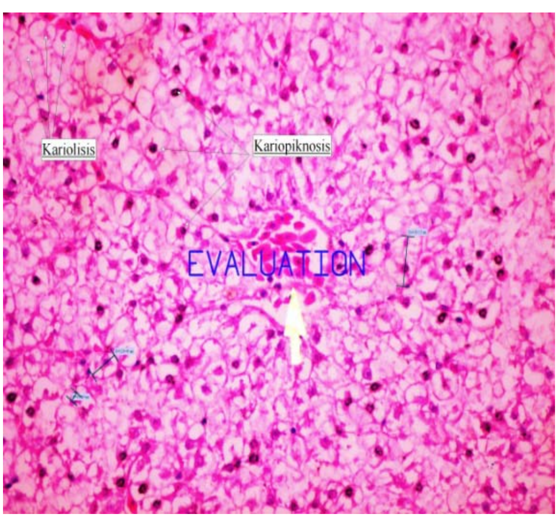

Figure 3 : Nuclear karyolysis and karyopyknosis

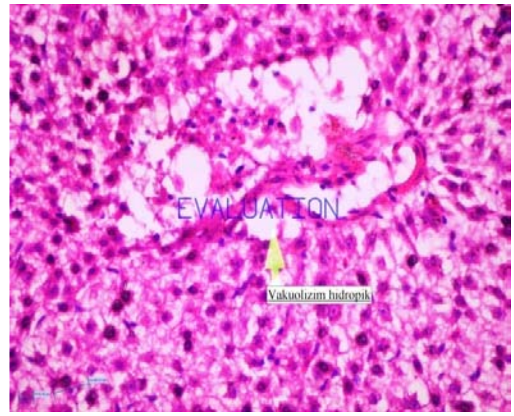

Figure 4 : Hydropic vacuolation (HydVac)

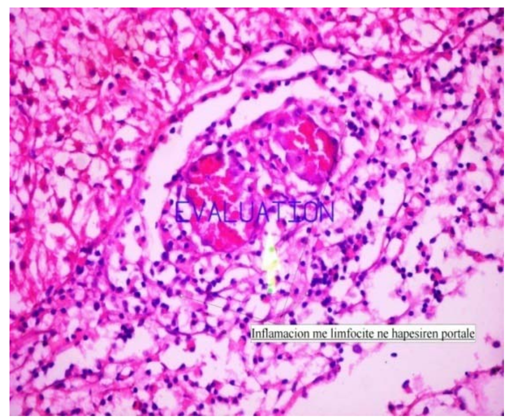

Figure 5 : Inflammation with lymphocytes in portal areas

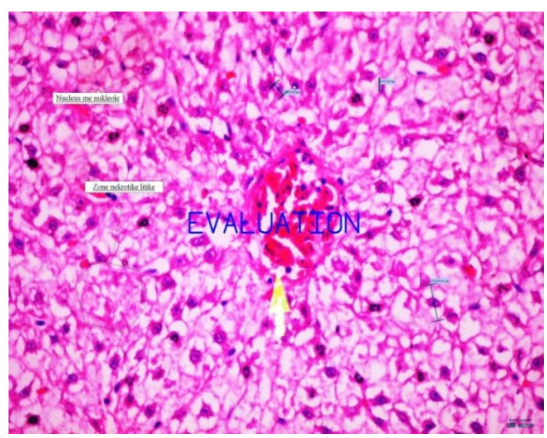

Figure 6 : Lyctic necrosis areas

IV. Conclusion

Based on the results of our research we can conclude that histopathology of fish liver is a good bioindicator and can be used for detection of chemical pollution in fish. It can be concluded that Sitnica River is a polluted river mainly by industrial and urban discharge of liquid waste products. It is recommended to treat different wastes before discharging to the natural water sources to avoid the negative effects of pollutants. As a consequence

Global Journal of Science Frontier Research (D) Volume XIII Issue V Version I Year 2013

legal actions need to be taken in order to prevent environmental pollution on the site.

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Global Journal of Science Frontier Research
Agriculture and Veterinary
Volume 13 Issue 5 Version 1.0 Year 2013
Type : Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 2249-4626 & Print ISSN: 0975-5896

Genetic Divergence Studies in Clusterbean [*Cyamopsis Tetragonoloba* (L.) Taub]

By P. Shabarish Rai. & P. R. Dharmatti
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Abstract - Thirty one genotypes of clusterbean collected from various sources were assessed for genetic divergence using Mahalanobis D^2 technique. The genetic material exhibited wide range of genetic diversity for all the characters investigated and grouped into 3 different clusters. The maximum intra cluster distance was observed in cluster I indicated that genotypes are having diverse genetic architecture. The intercluster distance was high between cluster II and cluster III, this indicated wide range of variability among clusters. The percent contribution towards genetic diversity was high for pod yield per hectare (26.02) followed by pod length (18.06) and plant height (14.62). On the basis of intercluster distance and per se performance observed in the present study a hybridization programme involving genotypes for a specific character has been chosen using cluster mean.

Keywords : genetic diversity, clusterbean, tocher's method, cluster distance.

GJSFR-D Classification : FOR Code: 070399, 079999

GENETIC DIVERGENCE STUDIES IN CLUSTERBEAN CYAMOPSIS TETRAGONOLOBA L. TAUB

Strictly as per the compliance and regulations of :

Research | Diversity | Ethics

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I. Introduction

Clusterbean or Guar [*Cyamopsis tetragonoloba* (L.) Taub] (2n = 14) is a drought tolerant annual legume crop. It is an important legume whose cultivation is mainly concentrated in marginal and submarginal soils receiving low rainfall. In India, it is an important legume crop and about three- forth of the global clusterbean cultivation since ancient times (Vavilov, 1951). In India, clusterbean occupies an area of 2.20 million hectares with a production of 0.60 million tons (Singh *et al.,* 2009). In North Indian states like Rajasthan, Haryana, Gujarat and Punjab it is mainly cultivated for guar gum production and for forage, whereas in South India it is being cultivated for vegetable purpose. In Karnataka it is being grown in limited area and is cultivated mainly in northern districts like Dharwad, Belgaum, Bijapur, Haveri *etc.* for tender vegetable pods and it is cultivated year round.

Guar is mainly cultivated for food, feed and fodder. Its young pods are used as vegetables, which also known for cheap source of energy (16 Kcal), moisture (8 g), protein (3.2 g), fat (1.4 g), carbohydrate(10.8 g), Vitamin A (65.3 IU), Vitamin C (49 mg), calcium (57 mg) and iron (4.5 mg) for every 100 g of edible portion (Kumar and Singh, 2002). Guar being leguminous crop, it improves fertility of soil by fixing considerable amount of atmospheric nitrogen and adding organic matter. Guar meal and seeds are the source of high protein and nutritious feed to the cattle. Its seed is also used for extraction of gum; hence it has emerged as a new industrial crop with high export value. Because of high absorbent capacity of guar gum it has diversified uses in paper, textiles, cosmetics, mining, explosives, oil industry, paints and bakery products. India occupies top position in guar gum and it has earned Rs. 1275 crores of foreign exchange (Kumar and Singh, 2006). Despite the importance of this crop, only limited breeding work has been done and very little attention has been given for its genetic improvement in the past in order to enhance the productivity level.

Information on the nature and magnitude of genetic diversity present in the genotype is pre-requisite. Parents should be selected on the basis of combining ability and F_1 heterosis for selecting high yielding varieties through hybridization (Arunachalam, 1989). Literature available on the nature and magnitude of diversity in clusterbean indicates that the studies of this kind are scanty and not properly documented. Therefore an attempt in the present investigation was made to study degree of genetic diversity in a set of 31 genotypes of clusterbean collected from different location.

II. Material and Methods

The material consisted of 31 phenotypically superior and diverse genotypes of clusterbean from different sources (Table 1). All these genotypes were evaluated in Randomised complete block design with two replications at Main agricultural research station, University of Agricultural sciences, Dharwad, during *kharif 2009*. Each genotype is sown in a single row of 10 m long as experiment plot, spacing followed is 45 cm between rows and 20 cm between plants within row. Optimum cultural practices followed as per University recommendations. For recording various observations five plants in each experimental plot were selected randomly by avoiding border plants. Observations recorded in the present investigation were plant height (cm), number of branches per plant, days to 50% flowering, number of pod clusters per plant, number of pods per plant, number of pods per cluster, pod length (cm), pod width (mm), seeds per pod, total yield per plant (g) and pod yield per hectare (t).

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The average data was subjected for statistical analysis and Mahalanobis D^2(1928) statistics was used to study genetic divergence. Group constellation was performed according to the method suggested by Tocher, Contribution of individual trait towards genetic divergence was quantified on the basis of coefficient of variation at genotypic and inter-cluster levels (Vavilov, 1951).

III. Results and Discussion

Analysis of variance showed highly significant difference among the genotypes for all the eleven characters studied. This suggested the presence of appreciable amount of diversity among the genotypes under study. The 31 genotypes are grouped into 3 clusters (Table 2). Cluster I included maximum of 29 genotypes, followed by cluster II and Cluster III had single genotype.

The clusterbean accessions from different origin were accommodated in same cluster indicating their close affinity. These results suggested that the accessions within the cluster might have some degree of ancestral relationship; on the other hand the accession collected from the same district was distributed in different clusters indicating geographical diversity may not be necessarily related with genetic diversity. Therefore, the selection of accessions for hybridization to generate new gene combination should be based on genetic diversity rather than geographical diversity. Similar findings of Henry and Krishna(1990), Raghu *et al.*(2008) and Singh *et al.*(2003) collaborated that the distribution of genotypes from different agro-ecological locations into cluster was random indicating geographical distribution doesn't necessarily exhibit genetic divergence.

Among the clusters, cluster I had maximum intracluster distance (15.28). Minimum intra cluster distance was recorded by cluster II and cluster III as included single genotype in each cluster (Table 3). The maximum inter cluster D^2 values (Table 3) was recorded between cluster I and cluster III (50.31) followed by Cluster II and Cluster III (44.21) suggested wide diversity among the genotypes between the group and crossing between the genotypes of clusters would result in heterotic combinations as reported by Singh *et al.*(2003) and Mathur and Henry (2001). Minimum D^2 value between cluster I and cluster II indicates close relationship among the genotypes of these clusters and had maximum of similar gene complexes among them.

Apart from genetic divergence due importance should be given to the performance of genotypes and character with maximum contribution towards divergence (Table 5). The contribution of various traits was worked out from their rank and maximum contribution (26.02%) was from Yield per hectare followed by pod length (18.06), plant height (14.62%), days to 50% flowering (9.68%), pods per plant (6.88%), Number of branches (5.81%), clusters per plant and number of seeds per pod (3.23%).

The mean value of cluster (Table 5) for all the characters was calculated which indicated that Cluster III had desirable mean values for early flowering, plant height, number of branches, pod length, pod width and number of seeds per pod. High mean value for indicated by cluster I for clusters per plant, pods per cluster and pods per plant. Whereas cluster II had highest mean value for pod yield per plant and yield per hectare. Hence these characters may be considered during selection of genotypes for further improvement.

As such based on intercluster distance and character with higher contribution to D^2 values there is scope for varietal improvement through hybridization programme involving genotypes of cluster III with genotypes possessing desirable characters of cluster II (50% flowering, clusters per plant, pods per cluster, pod yield per plant and yield per hectare) and cluster I (Number of pods per cluster and pods per plant).

It was evident from the study that there was considerable degree of variability for vegetable pod yield and its component characters. A few of the most promising genotypes for vegetable pod yield were line 22, line 25, line16, RB-1, JKD-1 and Pusa Navbahar. The genotypes like Sarphan, Pusa Navbahar, line 22 and line 23 were early flowering. The genotype line 22 (185) and line 14 (165.67) produced more number of pods per plant, pod breadth found highest in Pusa Navbahar, Varsha and Sarphan. Apart from these characters there are other desirable characters like pod length found highest in Pusa Navbahar.

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Table 1 : Source and place of collection used in the study of clusterbean genotypes

Source	Number of genotypes	Genotypes
Dharwad	1	Pusa Navbahar
UAS Dharwad	14	BJ-1, RB-1, JKD-1, Line15, Line16, Line17, Line18, Line19, Line20, Line21, Line22, Line23, Line24, Line25.
KRCCH Arabhavi	10	Line1, Line2, Line3, Line4, Line5, Line6, Line7, Line8, Line9, Line10, Line 11, Line 12, Line 13, Line 14, Line 15.
Sarphan seeds Ltd	1	Sarphan
Mahyco	1	Varsha

Table 2 : Grouping of clusterbean genotypes based on D^2 Values

Cluster	Name of genotypes	Number of genotypes
I	Line 1, line 2, line 3, line 4, line 5, line 6, line 7, line 8, line 9, line 10, line 11, line 12, line 13, line 14, line 15, line 16, line 17, line 18, line 19, line 20, line 21, line 22, line 23, line 4, line 25, BJ-1, JKD-1, Sarphan, Varsha.	29
II	RB-1	1
III	Pusa Navbahar	1

Table 3 : Average intra and inter cluster D^2 values of clusterbean genotypes

Cluster Distances	Cluster I	Cluster II	Cluster III
Cluster I	15.28	34.13	50.31
Cluster II		0	44.21
Cluster III			0

Table 4 : Percent contribution of 11 characters towards diversity in clusterbean genotypes

Characters	Percent Contribution	Order of contribution
50% flowering	9.68	IV
Plant height	14.62	III
Number of branches	5.81	VII
Clusters per plant	3.23	VIII
Pods per cluster	7.74	V
Pods per plant	6.88	VI
Pod length	18.06	II
Pod width	2.37	IX
Number of seeds per pod	3.23	VIII
Pod yield per plant	2.37	IX
Pod yield per hectare	26.02	I

Table 5 : Cluster means for 11 characters in clusterbean genotypes

Cluster Means	Cluster I	Cluster II	Cluster III
50% flowering	35.26	42.5	30.5
Plant height	39.07	94.75	100.85
Number of branches	5.79	6.75	0
Clusters per plant	28.53	32.5	14
Pods per cluster	6.97	14.1	7.97
Pods per plant	119.1	113.9	75.5
Pod length	5.44	6.23	10.1
Pod width	7.08	7.24	10.17
Number of seeds per	6.34	6	7.6
Pod yield per plant	120.1	173.35	155.59
Pod yield per hectare	13.62	18.74	16.8

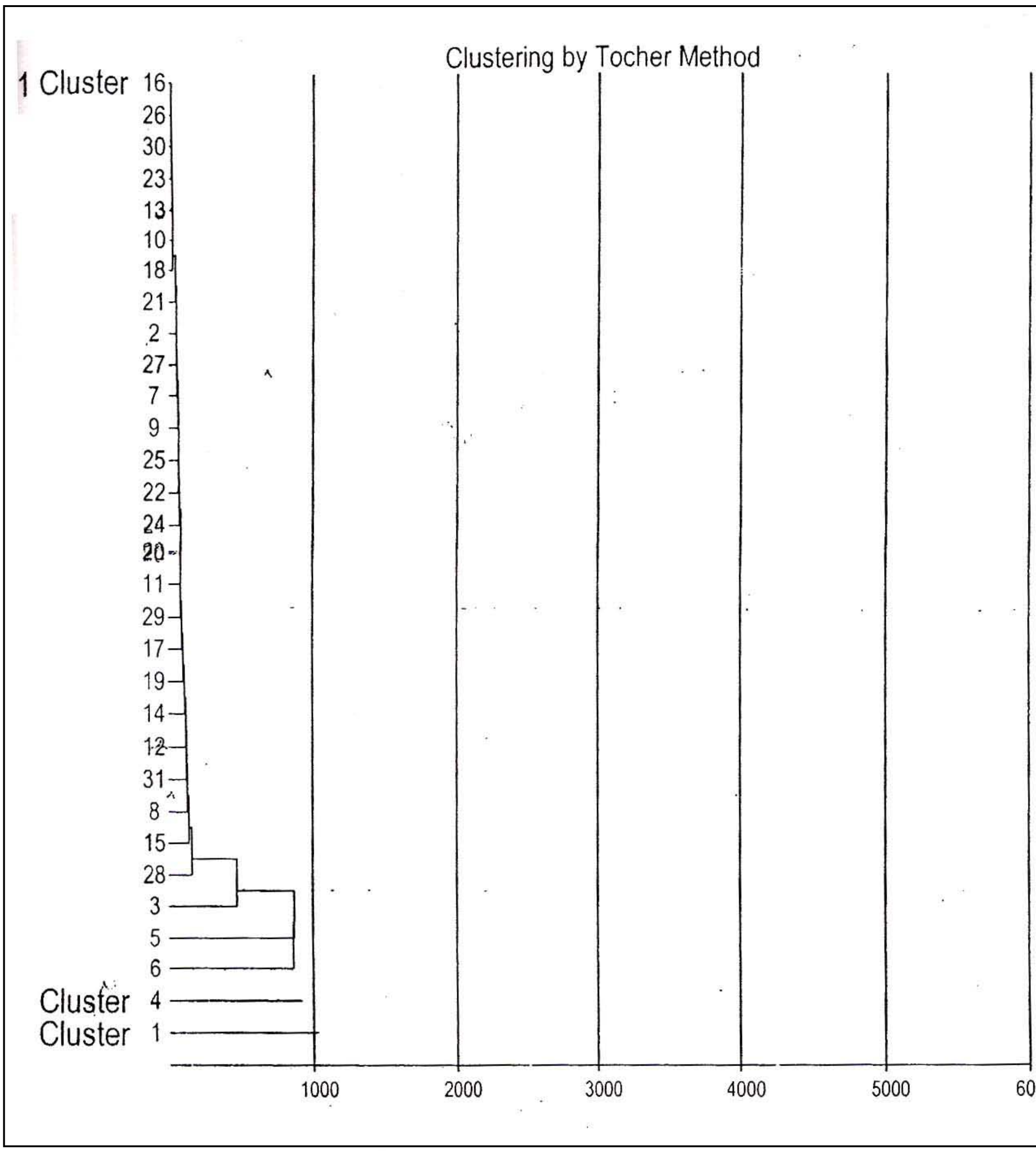

Figure 3 : Cluster pattern of 31 clusterbean genotypes

Global Journal of Science Frontier Research
Agriculture and Veterinary
Volume 13 Issue 5 Version 1.0 Year 2013
Type : Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 2249-4626 & Print ISSN: 0975-5896

Evaluation and Association Mapping for Drought Tolerance in Sorghum [*Sorghum Bicolor* (L.) Moench]

By Yohannes Besufekad & Kassahun Bantte
Jimma University

Abstract - As drought is a major production constraint, there is a need to develop drought tolerant varieties which in turn requires identification of genotypes that carry genes or QTLs associated with drought tolerance. Hence, the objectives of this study were to identify and map chromosomal regions associated with drought tolerance and to identify SSR markers tightly linked to these QTLs and to identify drought tolerant sorghum genotypes. Phenotypic and genotypic coefficients of variations were moderately high at both locations. The population structure analysis revealed four distinct clusters for 151 accessions studied. A total of four SSR markers were found to be consistently associated with days to 50% flowering, panicle exsertion and grain weight per panicle. These markers were localized with previously identified markers. Hence, the identified markers could be used in future marker-assisted selection programmes.

Keywords : association mapping, drought, population structure, QTLs, SSRs.

GJSFR-D Classification : *FOR Code: 079999, 300399*

EVALUATION AND ASSOCIATION MAPPING FOR DROUGHT TOLERANCE IN SORGHUM SORGHUM BICOLOR L. MOENCH

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Yohannes Besufekad [α] & Kassahun Bantte [σ]

Abstract - As drought is a major production constraint, there is a need to develop drought tolerant varieties which in turn requires identification of genotypes that carry genes or QTLs associated with drought tolerance. Hence, the objectives of this study were to identify and map chromosomal regions associated with drought tolerance and to identify SSR markers tightly linked to these QTLs and to identify drought tolerant sorghum genotypes. Phenotypic and genotypic coefficients of variations were moderately high at both locations. The population structure analysis revealed four distinct clusters for 151 accessions studied. A total of four SSR markers were found to be consistently associated with days to 50% flowering, panicle exsertion and grain weight per panicle. These markers were localized with previously identified markers. Hence, the identified markers could be used in future marker-assisted selection programmes.

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I. Introduction

Globally, sorghum is the fifth most important grain crop on the basis of production and grown across about 99 countries in the world. In Ethiopia 3.9 million tons with an average yield of 1.8 tons/ha is produced and it is one of the major food cereals after maize, teff and wheat [5]. More than 300 million people in developing countries consume sorghum as their principal food source especially for food-insecure peoples who are mainly living in the semiarid tropical regions [3].

Drought is one of the major limiting factors for yield stability in the semi-arid tropics, where rainfall is inadequate, non-uniform and erratic in distribution [6]. Worldwide, the yield loss each year due to drought was estimated to be around USD 10 billion [14]. Marker-assisted selection which involves the use of DNA markers is the most effective tool in a crop improvement through introgression of desirable genes of interest [17]. There is wide genetic variation for physiological and yield traits associated with tolerance to limited moisture stress within sorghum genotypes and these traits can be used for identifying drought tolerant genotypes of sorghum [13]. In plants, there are two approaches to identify genomic regions influencing expression of quantitative traits. The most common approach is to identify QTL in a segregating population through QTL mapping [18]. Alternatively, a relatively new approach being applied is association mapping, which is based on diverse populations being used to identify associations between allele frequencies and phenotypic variation [6]. Using 98 sorghum SSR markers and 107 accessions reported a total of 14 common SSR markers were associated with days to heading, days to flowering, culm length, number of tiller, number of panicle and panicle length [18].

Recently, [21] reported five markers associated with maturity date and plant height were identified on chromosomes 6, 9, and 10 using 242 sorghum accessions with 39 SSR markers which were evaluated at five environments. [25] reported two markers consistently associated with plant height at two environments using association mapping. In Ethiopia tremendous amount of variability exists in sorghum and a large number of accessions have been collected by the Institute of Biodiversity Conservation of Ethiopia [23].

II. Materials and Method

The field experiments were conducted in Ethiopia at Kobo Agricultural sub center site Amhara Regional State and Werer Agricultural Research Center Afar Regional State. Kobo is located 570 km East of Addis Ababa at altitude of 1513 masl and at latitude of $12^0$09'N and $39^0$38'E longitude. Werer Agricultural Research Center is located 278 km East of Addis Ababa at altitude of 740 masl and at latitude of $9^0$16'N and $40^0$9'E longitude.

The experimental materials consisted of 151 accessions of sorghum (*Sorghum bicolor*) having a chromosome number of 2n=2x=20. These accessions were collected by Institute of Biodiversity Conservation of Ethiopia from sorghum growing regions of Ethiopia. The field experiments in both locations were laid out in alpha lattice design, with three replications having eighteen blocks per replication. In both trials irrigation water was provided after sowing to ensure uniform germination. All the management practices were

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uniformly applied to all plots using the recommended practices. Phenotypic trait data were collected during plant growth and maturity for seven traits (days to 50% flowering, plant height, panicle exsertion, tiller number, panicle weight, grain weight per panicle and hundred grain weight) based on sorghum descriptor list [7].

a) DNA isolation and marker genotyping

Seedlings of 151 genotypes were raised in the green house and fresh leaves from 14 days old seedlings were harvested and dried with silica gel in zip locked plastic bag. Total genomic DNA was extracted following a modified CTAB (Cetyl Trimethyl Ammonium Bromide) extraction protocol [11].

The quality and quantity of the extracted DNA was determined by comparing the fluorescence of aliquots of DNA samples with a known concentration of λ-DNA after running them on 0.8% ((0.8g agarose dissolved in 100ml 1xTBE (Tris-Boric Acid-EDTA) buffer)) agarose gel that contained 0.3 μg/ml ethidium bromide solution. At the end of electrophoresis, the gel was visualized using UV light and photographed using a video capture (Flowgen IS 1000). All samples were normalized to the same concentration level (50ng) and used for PCR.

A total of 39 SSRs markers, including 22 di, 9 tri, and 4 tetra nucleotide or longer motifs and 4 compound repeats were used. These SSR markers were selected based on their uniform distribution in the sorghum genome. Four of them from chromosome 1, 3, 5 and 6, five of them were on chromosome 2, 7 and 8, two of them from chromosome 4 and three from chromosome 9 and 10. The PCR amplification was performed using Gene-Amp PCR system 9600(PE-Applied-Biosystems) in 96-well plates in a total reaction volume of 10μl reaction mixture containing 1μl DNA template (50ng), 1μl 10x PCR buffer, 2μl $MgCl_2$, 1μl of reverse primer, 1.0 μl forward primer directly labeled with 6-FAM (VIC, NED, PET fluoresce dyes), 0.5μl of each dNTP, 0.04 μl Taq DNA polymerase and 3.46 μl H_2O. The amplification profile consisted of initial denaturation of the template DNA at 95°C for 3 minutes, followed by 35 cycles, each for 30 sec at 95°C (denaturation), 1min at 56°C (annealing), and 1 min at 72°C (extension), and a final extension at 72°C for 3 mins.

III. Data Analysis

Statistical analyses were performed on phenotypic data for variances, genotype x environment interaction and heritability. The association analysis was done by using mixed linear model (MLM) with TASSEL software version 4.1.15 [1]. The population structure in 151 sorghum accessions was analyzed using 39 SSR markers. Each individual was assigned to sub-populations based on membership proportion in each sub-population using the software STRUCTURE ver.2.3.4 [14]. STRUCTURE was run with the admixture model, a burn-in period of 10,000 and 10,000 Markov Chain Monte Carlo repetitions [4]. The K matrix was generated in SPAGeDi for MLM analysis in the Q+K model.

$$y = X\alpha + Q + K + \varepsilon$$

y=observed vector, X = genotype, $X\alpha$ = fixed effects, Q= is population structure cofactor, K= kinship matrix cofactor and ε = random residual effects.

a) Marker Localization

To validate the association study between identified markers in this study and those mapped in previous studies were physically localized to chromosome accordingly [9]. The physical position of markers determined from map viewer searched against the sorghum genome database presented in www.phytozome.net /sorghum (03 January 2013). Alternatively, chromosome location of some SSR markers was provided by [12]. Molecular markers were located on chromosomes based on the physical distances in Mb using Map Draw 2.2 [11].

IV. Results and Discussion

The analysis of variance indicated highly significant difference (P<0.001) among accessions for all studied trait. Locations effects were highly significant (P< 0.01) for days to 50 % flowering, plant height and panicle weight. The location x genotype interaction was significant (P< 0.05) for plant height and highly significant (P< 0.001) for days to 50% flowering and panicle weight indicating that genotypes showed differential performance for these traits at the two locations. Heritability was for panicle weight (38.39-39.88%) and grain weight per panicle (36.72-41.39%) exhibited moderately high heritability estimates at both locations.

The population structure analysis result showed that posterior probability (Ln(P(D)) was stopped increasing and plateaued, as described by [4] in the range of 2-12 subpopulations (Figure 1).

The most likely K observed from K=4 explained by the highest value of(Ln (P (D))and this number was [21, 22].

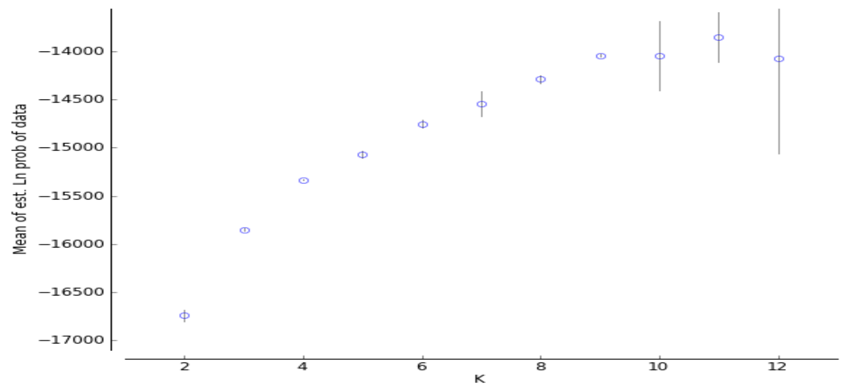

Figure 1 : Plot of mean likelihood L(K) and variance per K value from STRUCTURE on a dataset containing 151 individuals genotyped by 39 SSRs

The ad hoc statistics (ΔK) based on the second order rate of change of the likelihood showed a clear peak at the true value of K=4 (Figure 2). Therefore, k = 4 was selected and used for association analysis.

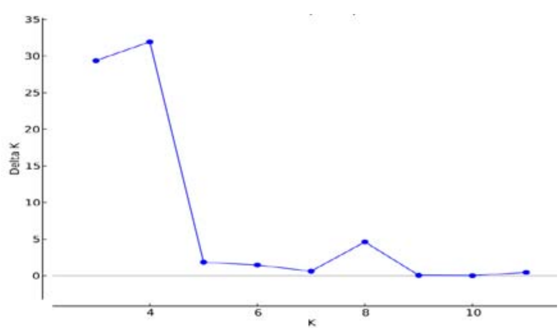

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Figure 2 : Plots for detecting the number of K groups that best fit the data by delta K values

Plots of ancestry estimates provided the estimated membership coefficients for each individual in each cluster. Each individual is represented by a single vertical line, partitioned into K colored segments that represent individual's estimated membership fraction in each of the K inferred clusters (Figure 3).

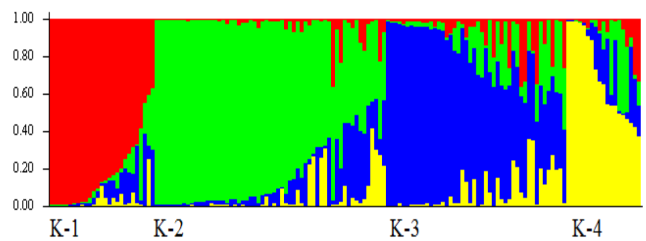

Figure 3 : Summary of plot estimates of population structure in the genotyped entries. The numbers (K-1, K-2, K-3 and K-4) were corresponding to the predefined population subgroups

To better examine patterns of association across different environments, associations with p-values between 0.05 and 0.01 were also shown. Association analysis based on two environments consistently four SSR markers Xtxp136, Xtxp015, mSbCIR300 and Xtxp278 associated with studied traits were identified (Table 1).

		Kobo					Werer				
Trait	Marker	F	P	Chr	Pos.	R^2(%)	F	P	Chr.	Pos.	R^2(%)
Days to 50 % flowering	Xtxp278	2.951	0.022	7	51.1	7.84	2.592	0.039	7	51.1	6.80
Panicle exsertion	mSbCIR300	2.754	0.03	7	58.3	7.28	2.896	0.024	7	58.3	6.72
Grain yield per panicle	Xtxp015	2.801	0.004	5	42.1	16	2.576	0.009	5	42.1	1.54
	Xtxp136	3.903	0.0225	5	57.6	5	3.478	0.017	5	57.6	6.93

p-values in bold are significant at $p < 0.05$

Only one marker (Xtxp015) was significantly associated with grain yield per panicle weight in Kobo and Werer. The reason that only one marker was associated with grain yield per panicle and for other traits was probably because inadequate coverage of the genome by the markers used in this study. Previous studies reported that one marker Xtxp145 was associated with sorghum grain yield on chromosome 6 [20].

[16] identified two SSR markers (Xtxp265 and Xtxp547) that were associated with days to flowering on chromosome 4 and 6 having phenotypic variance of 12 and 23 % respectively. In another study, [21] identified two markers (40-1897 and 44-2080) associated with days to 50 % flowering on chromosome 6 using 39 SSR markers and 242 sorghum accessions evaluated at five environments.

For days to 50 % flowering, alleles of 254bp and 248bp of marker Xtxp278 increased the days 50% flowering by approximately 1.01 day and 2.26 days each in 26 and 105 accessions respectively at Kobo. At Werer alleles of 254bp and 248bp of marker Xtxp278 reduced days to 50% flowering by approximately 0.49 days each in 26 accessions and increased 3.69 days each in 105 accessions.

For panicle exsertion, alleles 106bp and 112bp of marker mSbCIR300 increased panicle exsertion by 1.94 and 1.75 cm each in 130 and 16 accessions, respectively at Kobo. At Werer the same alleles 106bp and 112bp of marker mSbCIR300 increased panicle exsertion by 8.23 and 3.80 cm each in 130 and 16 accessions, respectively.

Two alleles 211bp and 215bp of marker Xtxp015 reduced grain yield approximately by 2 g and 2.19 g in 82 and 14 accessions, respectively. Allele 240bp and 237bp of marker Xtxp136 increased grain yield per panicle approximately by 2.16 g and 2.07 g in 78 and 68 accessions, respectively at Kobo. At Werer alleles 240bp and 243bp of marker Xtxp136 increased grain yield per panicle approximately by 0.53 g and reduced by 0.60 g in 128 and 12 accessions, respectively.

To validate the association between markers identified in this study and those mapped in previous studies, we physically localized our markers and previously mapped QTLs to the sorghum chromosomes.

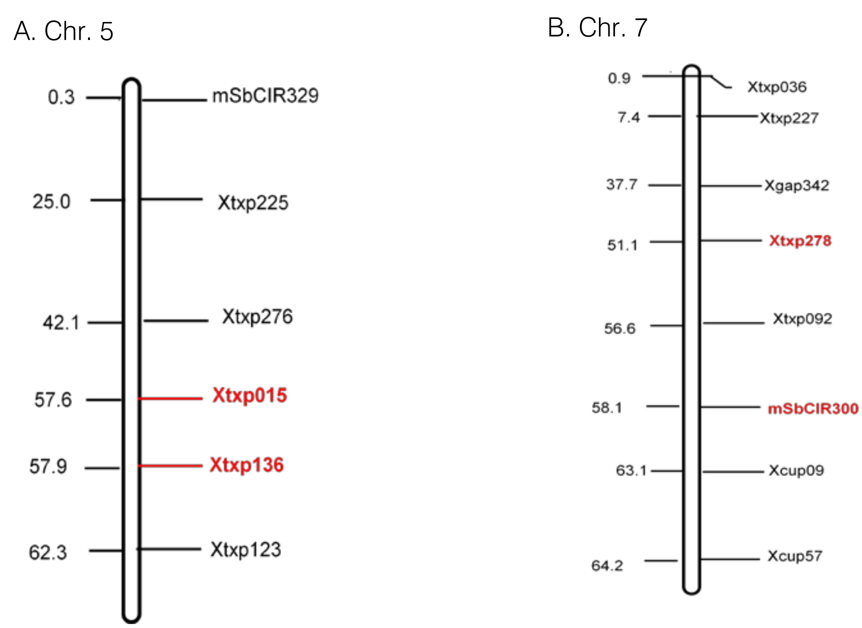

Figure 4 : Chromosomal locations of marker trait associations. The physical positions of markers in Mbp indicated on the left of the map and corresponding marker are indicated on the right. Identified markers in this study are showed in red color and markers previously mapped are in black color (A), shows SSR markers associated with grain weight per panicle (B), shows SSR markers associated with days to 50% flowering and panicle exsertion.

V. Conclusion

In this study, we identified two markers (Xtxp136 and Xtxp015) linked to grain yield per panicle, one (Xtxp278) to days to 50% flowering and one (mSbCIR300) to panicle exsertion consistently at two location. These SSR markers were co-localized with previously mapped QTLs for days to 50 % flowering, panicle exsertion and grain yield per panicle respectively. These markers could be used for marker-assisted selection of traits for drought tolerance improvement programmes and selection for drought tolerant genotypes. However, it should be validated further to improve the precision of study prior to apply in marker-assisted selection. By increasing the number of markers genome wide association mapping must be conducted to find strong association with traits. Additionally, the vicinity of the indentified loci will need to be further investigated to search for gene homologs that are known to regulate each trait.

Acknowledgements

This study was supported by the University of Jimma at Ethiopia and national research fund. We thank the reviewers for their critical comments to improve the manuscript.

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Global Journal of Science Frontier Research
Agriculture and Veterinary
Volume 13 Issue 5 Version 1.0 Year 2013
Type : Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 2249-4626 & Print ISSN: 0975-5896

Botanical Composition and Herbage Mass Estimation in Relation to Quality Status of Mauma Kharka *(Rangeland)* in the Taplejung District, Nepal

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Abstract - A study was conducted in Mauma Kharka, Olang Chung Gola VDC of Taplejung district, Nepal during June, 2010 to November, 2010 to determine the status of available herbage mass at transhumance system. Accordingly, herbage biomass estimation was done in three different slope categories using RCB design (<4%- plain category; 5-10% gentle slope, and 11-16% steep slope), each replicated for five times. The total fresh and dry weight of herbage mass Was estimated three times (July, August and September), taking 90 days growth period along with the botanical composition. The sample from each slope category harvested during July was also analyzed to determine CP, ether extract, NDF, ADF, ADL, cellulose, hemicelluloses and total ash. Results showed that the proportion of forbs were highest (60%), whereas cyperoids and grasses were similar and lower in proportion at each slope categories. The total dried herbage mass was statistically similar ($p>0.05$) along the three slope categories, with the mean dried weight 1.8 t/ha, 3.6 t/ha, and 2.6 t/ha for July, August, and September, respectively.

Keywords : CP, cyperoids, forbs, grass, rangeland.

GJSFR-D Classification : FOR Code: 270499p

BOTANICAL COMPOSITION AND HERBAGE MASS ESTIMATION IN RELATION TO QUALITY STATUS OF MAUMA KHARKA RANGELAND IN THE TAPLEJUNG DISTRICT, NEPAL

Strictly as per the compliance and regulations of :

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I. Barshila [α] & Naba R. Devkota [σ]

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Keywords : CP, cyperoids, forbs, grass, rangeland.

I. Introduction

Livestocks are the important component of Nepalese agricultural systems, as it contributes about 33% to the AGDP (CBS, 2001/2002). In the Agriculture Perspective Plan (APP, 1995), the future contribution of the livestock sector has been expected to reach 45 % to the total AGDP (CBS, 2001/02) by 2015. Nepal is rich in livestock population and abundance among the livestock species found in Nepal, Yaks and their crossbreds are reared in the mountainous regions of Nepal, with their visible role in supporting livelihood of mountain people. People living in the high elevation zones of eastern mountainous regions of Nepal have supported by these livestock species to the people (herders and traders) since thousands of years (Barsila, 2008). Yak and Chauries in Nepal are managed under the he transhumance or the migratory livestock system, where livestocks are moved from one place to another throughout the year (Tulachan and Neupane, 2000, Dong *et al.*, 2009) in order to exploit the vegetation of high alpine zones.

Rangelands are one of Nepal's most important resources, especially in the northern mountainous regions of the country. About 11% of Nepal's territory constitutes rangelands and most of it lies above the tree-line (Shrestha, 2001). It has been reported that rangeland ecosystems and their biological resources play a critical role in the region's overall economic development and in people's well being (Miller, 1997). However, rangeland as a cheaply available resource is depleted annually (Barsila, 2008), and therewith the rangeland productivity is declining mainly due to excessive stocking rate mostly in temperate pastures followed by subalpine and alpine pastures (Singh *et al.*, 1990; Miller, 1989 as cited in Barsila, 2008 and Devkota *et al.,* 2008). This raises a research question whether botanical composition differ to that of slope category so that appropriate management plan would be possible to formulate for improvement of rangeland resources. The major objective of this research was to identify most abundant pasture species and estimate general distribution of botanical composition across the three distinct slope categories in the selected rangeland of Taplejung district.

II. Methodology

The study was conducted during June, 2010 to November, 2010 (5 months) in a selected herd of Mr.

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Chungda Sherpa following a established transhumant route in the region. The selected pasture/rangeland has been situated at Mauma *Kharka*, (27^0 46' 11" North latitude and 87^0 48' 24" East longitudes, 4100 masl) of Olang Chung Gola VDC of the Taplejung district ($10^0$15' to $27^0$56' North latitude and $80^0$32 to $88^0$15' East longitudes with 777 to 8598 masl elevations) of Nepal which is north-east facing rangeland, inside Kanchanjunga Conservation Area. Three different slope categories of rangelands (plain, gentle slope and steep slope), which were available in Mauma *Kharka*, at 4100 m above mean sea level were purposively selected for this study. The research site with defined quadrate area were fenced during the June 2010, before the herd arrived for grazing. Three slope category was determined by using a Clinometers (Suunto, Germany), whereas it has further verified slope was calculated by using the slope formula:

percent slope = vertical distance/ horizontal distance x 100

Where,

Vertical distance was measured as a difference in elevation between two points, and horizontal distance was the distance from one point to the other and calculated by measuring distance with a rural and by applying the map scale of a topographical map. Finally, the slope % was defined and adjusted to plain category (less than 4% slope), gentle slope category (5-10% slope) and steep slope category (11-16% slope) The experimental design was a Completely Randomized Block (RCBD); one factor with three treatments, each replicated for 5 times. The treatments were slope categories. Altogether there were 15 experimental plots for each month study.

Above ground herbage mass productivity leaving 50 mm above the ground was estimated by using quadrate cutting on 5th July, 2010. In each quadrate, 0.5m × 0.5m area was fenced. Meanwhile, for each treatment and replication, the botanical composition was also determined under grasses, legumes, cyperoids, forbs, shrubs categories by separating individually for the harvested mass. The fresh re-growth from each treatment was also harvested twice at 30 days interval; each at 5^{th} August, and 5^{th} September, 2010. Likewise, individual herbage samples of ten most preferred pasture species were collected from the study site on the basis of herders experience and visual observation of grazed species and used for further the chemical composition determination by using proximate analysis. The harvested fresh herbage sample of most preferred pasture species were first sun-dried, and further oven dried at 60 ^{0}C for 48 hours at IAAS, Animal Nutrition laboratory. A proximate analytical method (AOAC, 1990) was used to determine the CP, NDF, ADF, ADL, EE, cellulose hemicelluloses and total ash. Different relevant government and non-government organizations such as NARC, DADO, DLSO, FAO, ICIMOD, IAAS were the source of secondary data for the study. Data obtained from the study was tabulated and analyzed by MS- EXCEL.

III. Results

This section deals about the results of study conducted on distribution of botanical composition of herbage mass under three distinct slope categories in Mauma, Taplejung harvested at July, August and September and most abundant pasture species that were found in the selected rangeland.

a) *Botanical composition of herbage at different slope categories*

The botanical composition of herbage mass differed in terms of species composed. The percentage of forbs were highest with the similar proportion of cyperoids and grasses (Figure 1, 2, 3). Botanical composition within the slope categories remained almost similar for all three months.

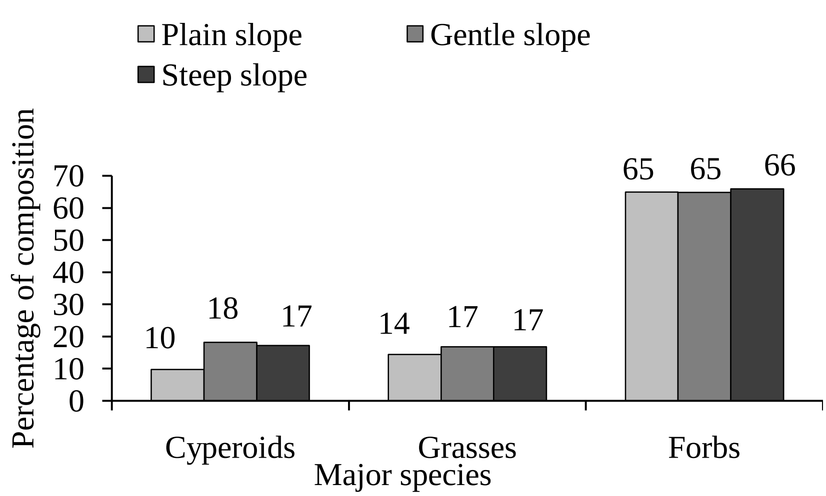

Figure 1 : Forage botanical composition at different slope categories (July, 2010) in Mauma rangeland, Taplejung

During July study, the proportion of cyperoids was 8% higher in gentle slope than the plain slope, but it was similar in gentle and steep slope. The proportion of grasses in gentle and steep slope was similar (17%) but was slightly higher than the plain slope. The proportion of forbs in all slope categories was similar which was about 50% higher than grasses and cyperoids. The highest percentage of forbs was 66% in steep slope.

During the study in August, percentage of forbs was higher that goes upto 61% (Figure, 2). Followed by the forb were grasses that contribute 37% in the plain slope whereas the proportion of grasses in gentle and steep slope was even lower than cyperoids. Likewise the percentage of cyperoids was somehow similar to grasses but slightly lower for plain slope (Figure 3).

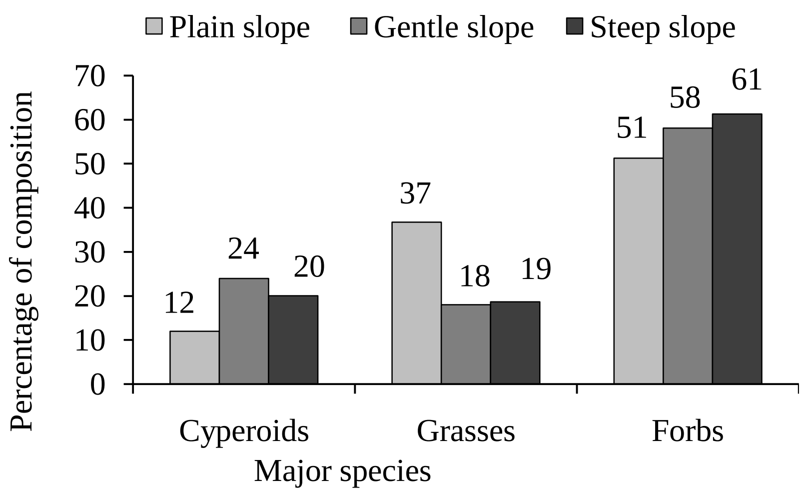

Figure 2 : Forage botanical composition at different slope categories (August, 2010) in Mauma rangeland,Taplejung

During September the proportion of forbs was highest that reached 73% for plain slope whereas percentage of forbs in other slope categories are exceeded 50% (Figure 3). Next to the forb was cyperiods to dominate icomposition but only in gentle and steep slope. The % composition of cyperoids ranged 13-20%. This situation of contribution of grasses as per different slope categories was similar to cyperoids.

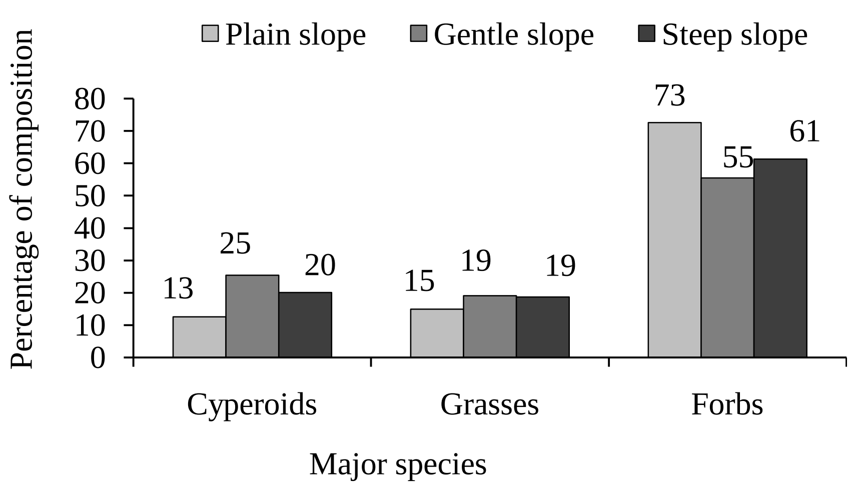

Figure 3 : Forage botanical composition at different slope categories (September, 2010) in Mauma rangeland, Taplejung

b) Chemical Composition of Most Abundant Pasture Species in the Experimental Area

The most preferred ten pasture species (on visual observation and herdes experiences) were *Kobresia humilis, Poa alpina, Poa himalayana,* Festuca sp., *Agrostis tenuis, Carex sp., Plantago major, Ranunculus heterophyllus, Kobresia nepalensis,* and *Potentilla sp*. The Chemical composition of ten most abundant pasture species has been reported in Table (1). Accordingly, the crude protein content was highest in *Poa alpana* (21.87%) with the lowest value for *Festuca species* (14%). Likewise, the ether extract was highest in *Kobresia nepalensis* (4.2%) and was lowest for *Agrostis tenuis* (2.4). The neutral detergent fiber (NDF) was highest in *Carax species* (68%) and lowest in *Potentilia species* (49.7%). The acid detergent fiber (ADF) was highest in *Festuca species* (58.7%) and lowest in *Poa alpana* (35.8%). Similarly, the acid detergent lignin (ADL) was highest in *Potentilia species* (23%) and lowest in *Kobresia species*. In the similar way, the cellulose content was highest in *Festuca species* (48%) and lowest in *Potentilia species* (22%). The value of other species fell in between these two figures. Likewise, the hemicelluloses content was highest in *Agrostis tenuis* (17.5%) and lowest in *Potentilia species* (4.6%). The total ash content was also highest in *Kobresia species* with the lowest for *Agrostis tenuis* (7%).

Table 1 : Chemical compositions (%) of most abundant pasture species during July (2010) in Mauma rangeland, Taplejung

Species	CP	EE	NDF	ADF	ADL	Cellulose	Hemicellulose	Total Ash
Kobresia nepalensis	21.35	4.2	63.08	52.21	15.6	36.61	10.87	9.2
Kobresia humilis	20.78	2.9	52.39	37.98	7.13	30.85	14.41	11.5
Poa alpina	21.87	3.2	60.32	35.82	8.82	27	24.5	9.5
Poa himalayana	19.38	3.3	54.22	44.21	10.29	33.92	10.01	11.2
Festuca sp.	14	2.7	68.11	58.74	10.82	47.92	9.37	8.8
Agrostis tenuis	13.78	2.4	70.25	52.63	11.33	41.3	17.62	7.3
Carex sp.	18.55	2.7	68.08	51.85	12.67	39.18	16.23	9.3
Plantago major	18.55	3.4	50.31	42.08	19.46	22.62	8.23	9.9
Ranunculus heterophyllus	19.38	2.8	54.53	48.53	19.51	29.02	6	10.2
Potentilla sp.	20.65	3.6	49.68	45.04	23.17	21.87	4.64	8

c) Total Herbage Mass Productivity Across the slope categories

The total fresh herbage mass production at first harvest (5th July, 2010) remained statistically similar ($P>0.05$) for all three categories of slope. However, the highest fresh herbage mass was for gentle slope (4.76 t/ha) and with the lowest value for steep slope (3.5 t/ha). The total dried herbage mass at first harvest also followed the similar trend of fresh herbage mass (Table 2). Accordingly, the total dry herbage mass production was statistically non-significant ($P>0.05$), but having highest dried mass production at gentle slope (2 t/ha) and lowest for plain slope (1.52 t/ha). The mean dried weight of all three slope category was 1.84 t/ha.

At second harvest (5th August, 2010), there was again similar performance ($P>0.05$) for total fresh herbage mass production across the slope categories, but highest yield was harvested for gentle slope (8.6 t/ha) with the lowest value for plain slope (6.1 t/ha) (Table 2). Here again, the dried weight of herbage mass was also found non-significant ($P>0.05$) at second harvest. Nevertheless, the highest dried mass was at gentle slope (4.1t/ha) with the lowest value for plain slope (1.7 t/ha). The average dried herbage mass for all three slope categories was to 3.6 t/ha in august.

At third harvest (5th September, 2010), the total fresh herbage mass production was again statistically similar, ($P>0.05$) but it was highest for gentle slope (12 t/ha) and lowest for plain slope (7 t/ha). The mean fresh herbage mass was 10 t/ha for all three categories of slope. Similarly, the dried herbage mass was also non-significant ($P>0.05$) as in the case of fresh herbage mass. Nevertheless the highest yield was for gentle slope (3 t/ha) with lowest value for plain slope (2.9 t/ha). The mean dry herbage mass of all three slope categories was 2.6 t/ha in September harvest.

The cumulated dried herbage mass of ninety days period from July to September was also non-significant ($P>0.05$) along different slope categories. Nevertheless the highest dried mass was for gentle slope (9.3 t/ha) with the lowest value for plain slope category (7.4 t/ha). The mean dried cumulated herbage mass of all three slope categories was 8 t/ha (Table 2).

Table 2 : The mean total herbage mass of mixed pasture species across the different slope categories (t/ha), in mauma rangeland, Taplejung (2010)

Treatments	First harvest (t/ha) (5th July 2010)		Second harvest (t/ha) (5th august 2010)		Third harvest(t/ha) (5th September 2010)		Cumulated dried wt(t/ha)
	Fresh wt	Dry wt	Fresh wt	Dry wt	Fresh wt	Dry wt	
Gentle slope	2.26 (4.76)	1.6 (2.08)	2.980 (8.62)	2.14 (4.16)	3.5 (12.16)	1.880 (3.08)	3.06 (9.30)

Gentle slope	2.26 (4.76)	1.6 (2.08)	2.980 (8.62)	2.14 (4.16)	3.5 (12.16)	1.880 (3.08)	3.06 (9.30)
Steep slope	1.980 (3.50)	1.54 (1.92)	2.640 (6.52)	2.08 (3.84)	3.30 (10.70)	1.560 (1.90)	2.8 (7.66)
LSD(0.05)	0.4371	0.2799	0.5194	0.3602	0.595	0.4643	0.4558
SEM(±)	0.1340	0.0858	0.1593	0.1105	0.182	0.1424	0.1398
F-probability	0.372^{ns}	0.294^{ns}	0.185^{ns}	0.069^{ns}	0.058^{ns}	0.295^{ns}	0.363^{ns}
CV (%)	14.0	12.7	13.1	12.4	12.8	18.2	10.8
Grand mean	4.19	1.84	7.09	3.65	10.15	2.65	8.14

Note: Figure in parenthesis are original value. The normally appeared figure are square root transferred value ($\sqrt{X}$ for value more than 10 and $\sqrt{X+0.5}$ for for value less than 10). Mean followed by same letter (s) within the column are not significantly different by DMRT at 5% level of significance.

*= significant at 5% level of significance (P<0.05)

**= significant at 1% level of significance (P<0.01)

NS= No significance differences (P>0.05)

SEM= Standard error of means

LSD= Least Significance difference of means at significance level α=0.05.

IV. Discussion

The above ground herbage mass in alpine meadows are affected by factors such as air temperature, altitudinal aspects, slope aspects, soil organic matter, soil available N and P and environmental factors (Wang *et al.,* 2007). The total herbage mass productivity across the slope category in the present study was statistically similar (P>0.05) for each month. This might be due to all slope categories selected in this experiment was in the north facing aspect. The primary productivity is depended upon spatial and temporal variation (Bouno *et al.,* 2010). North and north east aspect has the highest biomass in summer (Nikki *et al.,* 1980). Natural pasture yield in the north facing slopes was reported significantly higher than in the south facing slopes due to water availability (Gong *et al.,* 2008). Accordingly, biomass in the high alpine regions also reported highest in late rainy season mainly in July-August in Tibet (Long *et al.,* 1999b). Nevertheless August has the highest dry herbage mass productivity which is at par with Wang *et al.,* (2007). This results shows that slope would not be the determining factor in productivity of herbage but the time of grazing is important for the proper utilization of herbage mass. Biomass harvested in this experiment was comparatively higher than that reported by Devkota and Kolachhapati, (2010). Air temperature is crucial to be the single most important factor determining the biomass production of the alpine vegetation (Wang *et al.,* 2007), which might be favourable at July-August. The cumulated dried herbage mass was also found not significant (P>0.05) across the slope categories and found higher than the herbage mass reported by Devkota and Kolachhapati, (2010). This might be due to longer growing period and due to more proportion of forbs in the rangeland and enough rainfall during experimental periods. The botanical composition of the rangeland in every month and every slope slope categories shows that forbs are highly dominating,

The grazing management systems also affect the aboveground herbage mass and nutritive quality of pasture. The lowest dried weight yield in September at the present study might be due to the early withering of some of the early grown forbs succeeded by few species of *Potentilla spp*. and *Plantago major* which have lower NDF content but higher ADL content with the lowest cellulose content (Table 1).

The botanical composition of the rangeland in every month and every slope categories shows that forbs are highly dominating. In an abandoned pasture, the herbaceous forbs increased (Castro and Frietas, 2009). High forbs contribution in the herbage harvested would be due to the high grazing pressure in Mauma pasture (kharka), where the animals are freely grazed since the unknown past in the main pasture growing season. As majority of the pastures in Mauma rangeland are dominated by annual plants, forbs and sedges timely rainfall and snowfall are the critical factors for the growth of the good quality vegetation in the rangeland. Increase of number of invasive plants had been observed by Angassa and Oba (2010) in the pasturelands. Accordingly, high grazing pressure resulted high ADL content in pasture species (Glindemann *et al.,* 2009). These facts, somehow, resembles to the Mauma rangeland where forbs were dominating that showed visible and low quality herbage.

V. Conclusions

Botanical compositions of herbage like, cyperoids, grass forbs differed according to the slope categories. Forbs were in highest percentage cover in all slopes. Monthly distribution of herbage showed that cyperoids were distributed positively along slopes during each month but distribution of grasses and forbs were inversely related at gentle slope. Among the pasture species *Poa alpinae* had the highest CP content (21.8), *Carex sp.* had the highest NDF content (68) and *Festuca sp.* had the highest cellulose content (47.9). Although the CP content was highest in cyperoids followed by forbs and grasses. There was a dominance of forbs and cyperoids in the pastureland reflecting poor quality of herbage with its slowly deteriorating quality.

Acknowledgement

We would like to extend our sincere gratitude to Swaris Scholarship fund (with the Courtesy from Mr. S. Barsila, (Ph.D. Scholar) for providing financial support for this research and Directorate of Research, IAAS, for other technical supports.

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16. Use proper verb tense: Use proper verb tenses in your paper. Use past tense, to present those events that happened. Use present tense to indicate events that are going on. Use future tense to indicate future happening events. Use of improper and wrong tenses will confuse the evaluator. Avoid the sentences that are incomplete.

17. Never use online paper: If you are getting any paper on Internet, then never use it as your research paper because it might be possible that evaluator has already seen it or maybe it is outdated version.

18. Pick a good study spot: To do your research studies always try to pick a spot, which is quiet. Every spot is not for studies. Spot that suits you choose it and proceed further.

19. Know what you know: Always try to know, what you know by making objectives. Else, you will be confused and cannot achieve your target.

20. Use good quality grammar: Always use a good quality grammar and use words that will throw positive impact on evaluator. Use of good quality grammar does not mean to use tough words, that for each word the evaluator has to go through dictionary. Do not start sentence with a conjunction. Do not fragment sentences. Eliminate one-word sentences. Ignore passive voice. Do not ever use a big word when a diminutive one would suffice. Verbs have to be in agreement with their subjects. Prepositions are not expressions to finish sentences with. It is incorrect to ever divide an infinitive. Avoid clichés like the disease. Also, always shun irritating alliteration. Use language that is simple and straight forward. put together a neat summary.

21. Arrangement of information: Each section of the main body should start with an opening sentence and there should be a changeover at the end of the section. Give only valid and powerful arguments to your topic. You may also maintain your arguments with records.

22. Never start in last minute: Always start at right time and give enough time to research work. Leaving everything to the last minute will degrade your paper and spoil your work.

23. Multitasking in research is not good: Doing several things at the same time proves bad habit in case of research activity. Research is an area, where everything has a particular time slot. Divide your research work in parts and do particular part in particular time slot.

24. Never copy others' work: Never copy others' work and give it your name because if evaluator has seen it anywhere you will be in trouble.

25. Take proper rest and food: No matter how many hours you spend for your research activity, if you are not taking care of your health then all your efforts will be in vain. For a quality research, study is must, and this can be done by taking proper rest and food.

26. Go for seminars: Attend seminars if the topic is relevant to your research area. Utilize all your resources.

27. Refresh your mind after intervals: Try to give rest to your mind by listening to soft music or by sleeping in intervals. This will also improve your memory.

28. Make colleagues: Always try to make colleagues. No matter how sharper or intelligent you are, if you make colleagues you can have several ideas, which will be helpful for your research.

29. Think technically: Always think technically. If anything happens, then search its reasons, its benefits, and demerits.

30. Think and then print: When you will go to print your paper, notice that tables are not be split, headings are not detached from their descriptions, and page sequence is maintained.

31. Adding unnecessary information: Do not add unnecessary information, like, I have used MS Excel to draw graph. Do not add irrelevant and inappropriate material. These all will create superfluous. Foreign terminology and phrases are not apropos. One should NEVER take a broad view. Analogy in script is like feathers on a snake. Not at all use a large word when a very small one would be sufficient. Use words properly, regardless of how others use them. Remove quotations. Puns are for kids, not grunt readers. Amplification is a billion times of inferior quality than sarcasm.

32. Never oversimplify everything: To add material in your research paper, never go for oversimplification. This will definitely irritate the evaluator. Be more or less specific. Also too, by no means, ever use rhythmic redundancies. Contractions aren't essential and shouldn't be there used. Comparisons are as terrible as clichés. Give up ampersands and abbreviations, and so on. Remove commas, that are, not necessary. Parenthetical words however should be together with this in commas. Understatement is all the time the complete best way to put onward earth-shaking thoughts. Give a detailed literary review.

33. Report concluded results: Use concluded results. From raw data, filter the results and then conclude your studies based on measurements and observations taken. Significant figures and appropriate number of decimal places should be used. Parenthetical remarks are prohibitive. Proofread carefully at final stage. In the end give outline to your arguments. Spot out perspectives of further study of this subject. Justify your conclusion by at the bottom of them with sufficient justifications and examples.

34. After conclusion: Once you have concluded your research, the next most important step is to present your findings. Presentation is extremely important as it is the definite medium though which your research is going to be in print to the rest of the crowd. Care should be taken to categorize your thoughts well and present them in a logical and neat manner. A good quality research paper format is essential because it serves to highlight your research paper and bring to light all necessary aspects in your research.

Informal Guidelines of Research Paper Writing

Key points to remember:

- Submit all work in its final form.
- Write your paper in the form, which is presented in the guidelines using the template.
- Please note the criterion for grading the final paper by peer-reviewers.

Final Points:

A purpose of organizing a research paper is to let people to interpret your effort selectively. The journal requires the following sections, submitted in the order listed, each section to start on a new page.

The introduction will be compiled from reference matter and will reflect the design processes or outline of basis that direct you to make study. As you will carry out the process of study, the method and process section will be constructed as like that. The result segment will show related statistics in nearly sequential order and will direct the reviewers next to the similar intellectual paths throughout the data that you took to carry out your study. The discussion section will provide understanding of the data and projections as to the implication of the results. The use of good quality references all through the paper will give the effort trustworthiness by representing an alertness of prior workings.

Writing a research paper is not an easy job no matter how trouble-free the actual research or concept. Practice, excellent preparation, and controlled record keeping are the only means to make straightforward the progression.

General style:

Specific editorial column necessities for compliance of a manuscript will always take over from directions in these general guidelines.

To make a paper clear

· Adhere to recommended page limits

Mistakes to evade

- Insertion a title at the foot of a page with the subsequent text on the next page
- Separating a table/chart or figure - impound each figure/table to a single page
- Submitting a manuscript with pages out of sequence

In every sections of your document

· Use standard writing style including articles ("a", "the," etc.)

· Keep on paying attention on the research topic of the paper

· Use paragraphs to split each significant point (excluding for the abstract)

· Align the primary line of each section

· Present your points in sound order

· Use present tense to report well accepted

· Use past tense to describe specific results

· Shun familiar wording, don't address the reviewer directly, and don't use slang, slang language, or superlatives

· Shun use of extra pictures - include only those figures essential to presenting results

Title Page:

Choose a revealing title. It should be short. It should not have non-standard acronyms or abbreviations. It should not exceed two printed lines. It should include the name(s) and address (es) of all authors.

Abstract:

The summary should be two hundred words or less. It should briefly and clearly explain the key findings reported in the manuscript--must have precise statistics. It should not have abnormal acronyms or abbreviations. It should be logical in itself. Shun citing references at this point.

An abstract is a brief distinct paragraph summary of finished work or work in development. In a minute or less a reviewer can be taught the foundation behind the study, common approach to the problem, relevant results, and significant conclusions or new questions.

Write your summary when your paper is completed because how can you write the summary of anything which is not yet written? Wealth of terminology is very essential in abstract. Yet, use comprehensive sentences and do not let go readability for briefness. You can maintain it succinct by phrasing sentences so that they provide more than lone rationale. The author can at this moment go straight to shortening the outcome. Sum up the study, with the subsequent elements in any summary. Try to maintain the initial two items to no more than one ruling each.

- Reason of the study - theory, overall issue, purpose
- Fundamental goal
- To the point depiction of the research
- Consequences, including definite statistics - if the consequences are quantitative in nature, account quantitative data; results of any numerical analysis should be reported
- Significant conclusions or questions that track from the research(es)

Approach:

- Single section, and succinct
- As a outline of job done, it is always written in past tense
- A conceptual should situate on its own, and not submit to any other part of the paper such as a form or table
- Center on shortening results - bound background information to a verdict or two, if completely necessary
- What you account in an conceptual must be regular with what you reported in the manuscript
- Exact spelling, clearness of sentences and phrases, and appropriate reporting of quantities (proper units, important statistics) are just as significant in an abstract as they are anywhere else

Introduction:

The **Introduction** should "introduce" the manuscript. The reviewer should be presented with sufficient background information to be capable to comprehend and calculate the purpose of your study without having to submit to other works. The basis for the study should be offered. Give most important references but shun difficult to make a comprehensive appraisal of the topic. In the introduction, describe the problem visibly. If the problem is not acknowledged in a logical, reasonable way, the reviewer will have no attention in your result. Speak in common terms about techniques used to explain the problem, if needed, but do not present any particulars about the protocols here. Following approach can create a valuable beginning:

- Explain the value (significance) of the study
- Shield the model - why did you employ this particular system or method? What is its compensation? You strength remark on its appropriateness from a abstract point of vision as well as point out sensible reasons for using it.
- Present a justification. Status your particular theory (es) or aim(s), and describe the logic that led you to choose them.
- Very for a short time explain the tentative propose and how it skilled the declared objectives.

Approach:

- Use past tense except for when referring to recognized facts. After all, the manuscript will be submitted after the entire job is done.
- Sort out your thoughts; manufacture one key point with every section. If you make the four points listed above, you will need a least of four paragraphs.

- Present surroundings information only as desirable in order hold up a situation. The reviewer does not desire to read the whole thing you know about a topic.
- Shape the theory/purpose specifically - do not take a broad view.
- As always, give awareness to spelling, simplicity and correctness of sentences and phrases.

Procedures (Methods and Materials):

This part is supposed to be the easiest to carve if you have good skills. A sound written Procedures segment allows a capable scientist to replacement your results. Present precise information about your supplies. The suppliers and clarity of reagents can be helpful bits of information. Present methods in sequential order but linked methodologies can be grouped as a segment. Be concise when relating the protocols. Attempt for the least amount of information that would permit another capable scientist to spare your outcome but be cautious that vital information is integrated. The use of subheadings is suggested and ought to be synchronized with the results section. When a technique is used that has been well described in another object, mention the specific item describing a way but draw the basic principle while stating the situation. The purpose is to text all particular resources and broad procedures, so that another person may use some or all of the methods in one more study or referee the scientific value of your work. It is not to be a step by step report of the whole thing you did, nor is a methods section a set of orders.

Materials:

- Explain materials individually only if the study is so complex that it saves liberty this way.
- Embrace particular materials, and any tools or provisions that are not frequently found in laboratories.
- Do not take in frequently found.
- If use of a definite type of tools.
- Materials may be reported in a part section or else they may be recognized along with your measures.

Methods:

- Report the method (not particulars of each process that engaged the same methodology)
- Describe the method entirely
- To be succinct, present methods under headings dedicated to specific dealings or groups of measures
- Simplify - details how procedures were completed not how they were exclusively performed on a particular day.
- If well known procedures were used, account the procedure by name, possibly with reference, and that's all.

Approach:

- It is embarrassed or not possible to use vigorous voice when documenting methods with no using first person, which would focus the reviewer's interest on the researcher rather than the job. As a result when script up the methods most authors use third person passive voice.
- Use standard style in this and in every other part of the paper - avoid familiar lists, and use full sentences.

What to keep away from

- Resources and methods are not a set of information.
- Skip all descriptive information and surroundings - save it for the argument.
- Leave out information that is immaterial to a third party.

Results:

The principle of a results segment is to present and demonstrate your conclusion. Create this part a entirely objective details of the outcome, and save all understanding for the discussion.

The page length of this segment is set by the sum and types of data to be reported. Carry on to be to the point, by means of statistics and tables, if suitable, to present consequences most efficiently.You must obviously differentiate material that would usually be incorporated in a study editorial from any unprocessed data or additional appendix matter that would not be available. In fact, such matter should not be submitted at all except requested by the instructor.

Content

- Sum up your conclusion in text and demonstrate them, if suitable, with figures and tables.
- In manuscript, explain each of your consequences, point the reader to remarks that are most appropriate.
- Present a background, such as by describing the question that was addressed by creation an exacting study.
- Explain results of control experiments and comprise remarks that are not accessible in a prescribed figure or table, if appropriate.
- Examine your data, then prepare the analyzed (transformed) data in the form of a figure (graph), table, or in manuscript form.

What to stay away from

- Do not discuss or infer your outcome, report surroundings information, or try to explain anything.
- Not at all, take in raw data or intermediate calculations in a research manuscript.
- Do not present the similar data more than once.
- Manuscript should complement any figures or tables, not duplicate the identical information.
- Never confuse figures with tables - there is a difference.

Approach

- As forever, use past tense when you submit to your results, and put the whole thing in a reasonable order.
- Put figures and tables, appropriately numbered, in order at the end of the report
- If you desire, you may place your figures and tables properly within the text of your results part.

Figures and tables

- If you put figures and tables at the end of the details, make certain that they are visibly distinguished from any attach appendix materials, such as raw facts
- Despite of position, each figure must be numbered one after the other and complete with subtitle
- In spite of position, each table must be titled, numbered one after the other and complete with heading
- All figure and table must be adequately complete that it could situate on its own, divide from text

Discussion:

The Discussion is expected the trickiest segment to write and describe. A lot of papers submitted for journal are discarded based on problems with the Discussion. There is no head of state for how long a argument should be. Position your understanding of the outcome visibly to lead the reviewer through your conclusions, and then finish the paper with a summing up of the implication of the study. The purpose here is to offer an understanding of your results and hold up for all of your conclusions, using facts from your research and generally accepted information, if suitable. The implication of result should be visibly described. Infer your data in the conversation in suitable depth. This means that when you clarify an observable fact you must explain mechanisms that may account for the observation. If your results vary from your prospect, make clear why that may have happened. If your results agree, then explain the theory that the proof supported. It is never suitable to just state that the data approved with prospect, and let it drop at that.

- Make a decision if each premise is supported, discarded, or if you cannot make a conclusion with assurance. Do not just dismiss a study or part of a study as "uncertain."
- Research papers are not acknowledged if the work is imperfect. Draw what conclusions you can based upon the results that you have, and take care of the study as a finished work
- You may propose future guidelines, such as how the experiment might be personalized to accomplish a new idea.
- Give details all of your remarks as much as possible, focus on mechanisms.
- Make a decision if the tentative design sufficiently addressed the theory, and whether or not it was correctly restricted.
- Try to present substitute explanations if sensible alternatives be present.
- One research will not counter an overall question, so maintain the large picture in mind, where do you go next? The best studies unlock new avenues of study. What questions remain?
- Recommendations for detailed papers will offer supplementary suggestions.

Approach:

- When you refer to information, differentiate data generated by your own studies from available information
- Submit to work done by specific persons (including you) in past tense.
- Submit to generally acknowledged facts and main beliefs in present tense.

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- To guard yourself and others from possible illegal use please do not permit anyone right to use to your paper and files.

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Topics	Grades		
	A-B	**C-D**	**E-F**
Abstract	Clear and concise with appropriate content, Correct format. 200 words or below	Unclear summary and no specific data, Incorrect form Above 200 words	No specific data with ambiguous information Above 250 words
Introduction	Containing all background details with clear goal and appropriate details, flow specification, no grammar and spelling mistake, well organized sentence and paragraph, reference cited	Unclear and confusing data, appropriate format, grammar and spelling errors with unorganized matter	Out of place depth and content, hazy format
Methods and Procedures	Clear and to the point with well arranged paragraph, precision and accuracy of facts and figures, well organized subheads	Difficult to comprehend with embarrassed text, too much explanation but completed	Incorrect and unorganized structure with hazy meaning
Result	Well organized, Clear and specific, Correct units with precision, correct data, well structuring of paragraph, no grammar and spelling mistake	Complete and embarrassed text, difficult to comprehend	Irregular format with wrong facts and figures
Discussion	Well organized, meaningful specification, sound conclusion, logical and concise explanation, highly structured paragraph reference cited	Wordy, unclear conclusion, spurious	Conclusion is not cited, unorganized, difficult to comprehend
References	Complete and correct format, well organized	Beside the point, Incomplete	Wrong format and structuring

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ISSN 9755896