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Irrigation System and Pattern of Crop Combination, Concentration and Diversification in Barddhaman District, West Bengal

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Abstract

In West Bengal, 53% of Net Shown Area (NSA) is cultivated under paddy. In Barddhaman, 97% of Gross Cropped Area (GCA) is used for cultivation of paddy and there is also aninter-block difference in the pattern of combination, intensification and diversification of crops.Using District Statistical Handbook, 2013 and Census report of Barddhaman, 2001, an attempt is made in this paper to find out the suitable cropping pattern in Barddhaman, West Bengal. The paper argues that the type of irrigation and soil health determine the combination of crop in the district.

Keywords: Crop Combination, Crop Concentration, Crop Diversification, Groundwater irrigation and Fertility of Soil

1.0. Introduction

Agriculture plays a dominant role in economic development through supplying food for the nation, generating opportunities of employment, and sharing of national GDP as well as providing raw materials for agro-based industries (Johnstone and Mellor, 1961). In India, 60% of people are dependent on agriculture (Paul, 2015). After green revolution in India (1966-67), chemical fertilizer is being used to improve productivity along with high yield variety seeds, pesticides and irrigation (Snapp et al., 2010; Chattopadhyey, 1984). During this period, mono-crop cultivation has been over emphasized which in turn destroyed the traditional crop sequence, crop calendar and crop rotation

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(Thapar, 1973). Consequently, agricultural landuse has drastically been changed from multicrop (cereals,oil seeds, pulses) to mono crop (paddy or wheat). In pre-green revolution period, rice was the dominant crop of West Bengal in general and of Barddhaman in particular. Noticeably, gram was found as second dominant crop in the district in 1950-52 (Bhatia, 1965). But, in 2013, 97% of gross cropped area in Barddhaman is earmarked only for rice through obliterating earlier cropping system of oil seed and pulses.

Crop rotation and diversification were practiced intraditional system of farming to control weeds, pest and soil erosion, and to maintain soil fertility (Singh and Sidhu, 2004; Jodha and Singh, 1990; El-Nazer and McCarl, 1986;Battese and Fuller, 1972; Brust&Stinner, 1991; Summer, 1982; Leibman&Dyck, 1993; Blanco-Canqui&Lal, 2004). Diversity of crops helps to sustain functional capacity and resilience in agro-ecosystem through increasing biodiversity along with performance of genotype in different niches (Vandermeer et al. 1998; Brust and Stinner, 1991; Sumner, 1982). Diversification of crops includes all crops other than rice (Husain, 1996; Metzel and Ateng, 1993) whereas horizontal diversification of agriculture involves various activity or cultivation of differentcrops in a calendar (Taylor, 1994). Level of crop diversification is dependent on geo-climatic or agro-climatic, socio-economic and technological advancement of a region (Husain, 1996; Quasem and Rehman, 1993; Singh and Dhillon, 1984).

During 1965-71, 49.7% area under pulses declined in Punjab to flourish wheat-paddy system (Thapar, 1973). Adverse consequences of this system are deceleration in productivity, unemployment in agriculture, over exploitation of ground water and declination in soil fertility (Sidhu and Johl, 2002; Singh et al., 1997). Recently, crop diversification has been mooted in Panjab to replace winter wheat with oil seed or pulse to restore nitrogen balance in soil and sound economic as well as societal benefit (Editorial, EPW, 2002).

The study of combination of crops is an important tool to assess the distribution of cropping system to assess suitable combination of crops (Weaver, 1954). Greater the dominance of a crop, the lesser is the competition among crops in an areal unit (Bhatia, 1965; Singh and Dhillon, 1984). Specialization of crop is not desirable as it leads to loss of productivity, decline of fertility of soil, outbreak of pest and pathogen (Quasem and Rahman, 1993; Husain, 1996; Lin, 2011; Singh and Dhillon, 1984; Zohir, 1993).Hence, combination, concentration and diversification of crops are important tools in agricultural regionalization to find out the specificity of crops, causes of

specialization and remedies for agro-ecosystem. The objectives of the research study are to find out the combination of crops, concentration and crop land occupancy of rice (*aman* and *boro*) and potato along with diversification of crops in Barddhaman District.

2.0 Study Area

The geographical area of Barddhaman District is 7024 sq km. The district is constituted of six sub-divisions and 31 C.D. Blocks.During last five decades, population density has been increased 342% from 312 persons/sq. km in 1961to 1099 persons/sq. km in 2011 (Census of India, 1951, and 2011). The principal crop of the district is rice which is cultivated in 97% of the gross cropped area. The net sown area is 4328 sq. km (61.61%) with physiological density of 79 cultivators/sq km.

2.0. Materials and Method

Materials

The research study has been done using secondary data of District Statistical Handbook of Burdwan, (2013), collected from Bureau of Applied Economic and Statistics, Government of West Bengal. The data on facilities of irrigation has been taken from village directory of Census of India, Government of India, (2001).

Methods

Calculation for Regionalization of Agriculture

The collected data have been calculated to find out the regions of agriculture on crop combination (Weaver, 1954), concentration, diversification and intensityusing following equations.

$CC = \frac{\sum d2}{n}$ where, CC= Crop combination

"d^2= difference between the actual crop percentage in a given unit and the percentage in the theoretical distribution,
n= the number of crops in a given combination (Weaver, 1954; Singh and Dhillon, 1984).

$Ci = \frac{Pae}{Par} \times 100$ where, C =crop concentration

Ci= crop concentration index
Pae=% of the crop 'a' to the total harvested area in an enumeration unit
Par=% of crops a to the total harvested area in the entire region

$CD = \frac{C}{n}$ where, CD= Crop diversification

c= %of total harvested area under 'n' crops
n= crops are those which individually occupy 5% or more of the total harvested area (Singh, 1984)

$CI = \frac{\sum aij}{\sum aio} \times \frac{Ni}{No}$ where, $ai_{j=}$ area under the i^{th} crop in the j^{th} year

$ai_{o=}$ area under the ith crop in the base year
Ni=net area shown in the j^{th} year
No=net area shown in the base year, (Hasain, 1996)

$Cci = \frac{aci}{til} \times 100$ where, Cci= Sharing of canal irrigation

aci = area under canal irrigation
til= total irrigated land

$Cgr = \frac{agr}{til} \times 100$ where, Cgr=Sharing of ground water irrigation

agr =area of ground water irrigation
til= total irrigated land

Representation

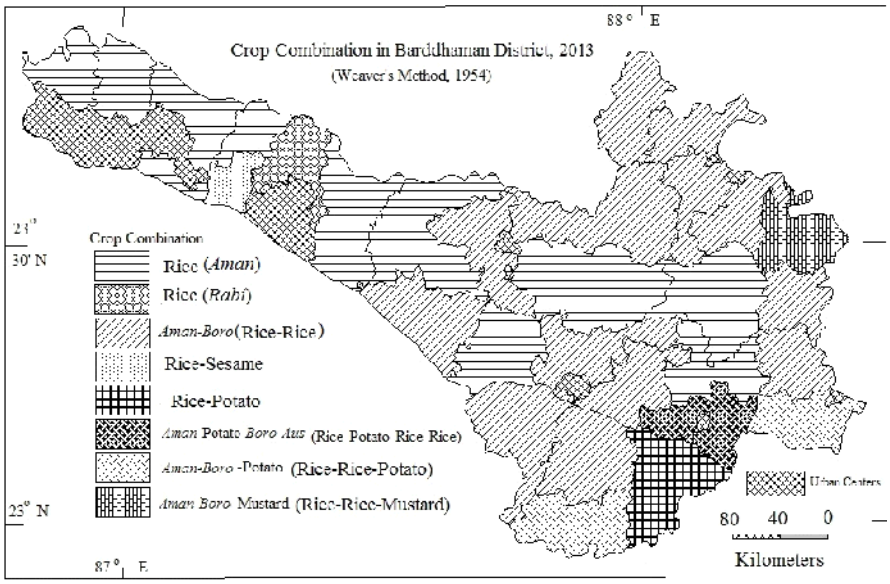
Linear and multiple regression have been done in MS excel, 2007 and Statistica 10.0 respectively. Thematic maps is prepared using Map Info 7.0. Correlation between variables has been calculated and tested its significance at N-2 degree of freedom [N-2=(31-2)=29].

3.0. Results

3.1. Crop Combination in Barddhaman District

After detail analysis of crop combination in BarddhamanDistrict, only rice (*aman)* has been found as suitable crop in Salanpur, Barabani, Jamuria, Pandabeswar, and Raniganj Blockswhere cultivation of rice is marginal with rain water and cultivation in *rabi* is not possible due to availability of water and low fertility of soil. Only rice (*boro)* has been observed as favourable combination in Faridpur-Durgapur Block because *boro* cultivation is dominant with tank irrigation. Rice (*aman)* is the convenient combination of crop in Kanksa, Ausgram - II, Bhatar, Galsi - II, Manteswar and Memari II due to sharing of more than 70% of GCA in *aman*. Rice-rice (a*man-boro)* is the pertinent crop combination in Burdwan I, Burdwan II, Raina I, Kalna I, Purbasthali I, Ketugram - I, II, Katwa I, II, Mangolkote and Galsi - II because

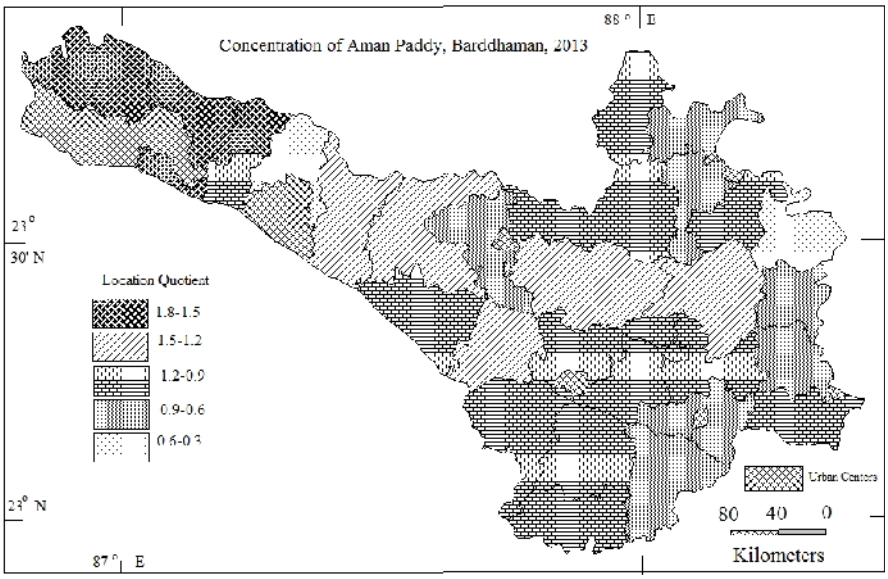
of sharing of more than 80% NSAin both *kharif* and *rabi* season. Rice-sesame is the convenient combination of crops in Andal because 62% and 36% of GCA are under rice and sesame respectively. In Jamalpur, rice-potato is found as suitable combination of crop due to sharing of 51% in rice and 37%of GCA in potato.The combination of rice (*aus*,pre-monsoon)-*rice* (*aman*, monsoon)-potato- rice (*boro*, post-monsoon) have shown the lowest deviation in Memari-I, where 48%, 25%, 13% and10% of GCA are cultivated with *aman*, potato, *boro* and *aus* respectively. In Raina -II, rice-rice-potato has been found as favourable combinationbecause 56%,19% and 18% of GCA are practiced by *aman*, *boro* and potato respectively. In this context, cropping season and weather condition should to be considered for potato cultivation. In Purbasthali II, rice-rice-mustard is the suitable combination of crops for sharing of 36%, 27%, and 20% of GCA under *aman*, *boro*, and mustard respectively (Map No.1).Grossly, in Barddhaman, 40.148% and 33.75% crop lands are used for the combination of *aman-boro* and *aman* respectively. Unfortunately, only 4.06%, 6.16% and 2.96% areas come under the combination of *aman*-potato, *aman-boro*-potato and *aman-boro*-mustard respectively.



Map No.1: Crop Combination, Barddhaman, 2013

3.2. Concentration of *Aman*

Aman is cultivated in 61.08% of GCA of the district. Location Quotient (LQ) value of 0.6-0.3 has been found in Faridpur-Durgapur due to sharing of 19% GCA in *aman*. LQ of 0.9-0.6 is noticed in Ausgram I, Ketugram - II, Katwa-I, Purbasthali-I, Kalna-I, Memari-I, and Jamalpur. Higher concentration of *aman* than average of the district (LQ 1.2-0.9) is observed in Burdwan- I, II, Raina-I, II, Khandoghosh, Memari-II, Kalna-II, Galsi - I, Mangolkote, Ketugram - I and Katwa-II due to intense canal irrigation system (Map No.2). Highest LQ (1.64) has been observed in Salanpur, Barabani, Jamuria, Pandabeswar, Raniganjbecause of lowest cropping intensity (100).

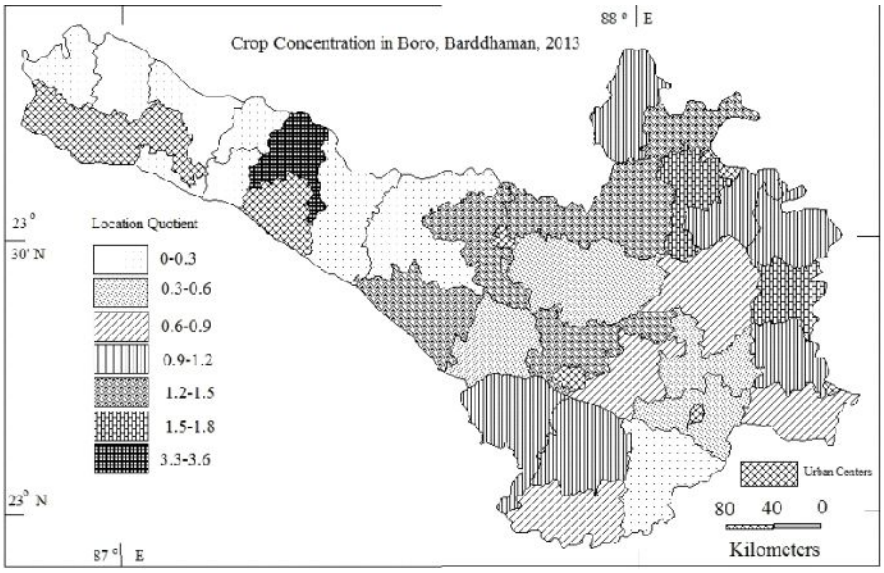


Map No. 2: Concentration of *Aman* Paddy, Barddhaman, 2013

3.3. Crop Concentration in *Boro*

Cultivation of *boro* is widely varied in Barddhaman due to insufficient supply of canal irrigation and availability of submersible irrigation in *rabi*. In this district, 23.88% of GCA is practiced with *boro*(65.2% of NSA in *rabi*). *Boro* paddy has not been cultivated in Salanpur, Jamuria, Andal, Barabani, Raniganj, Pandabeswar due to unavailability of water (0% and 9% land under canal and groundwater irrigation respectively). The lowest LQ (0-0.3) is found in Kanksa and Ausgram-IIin spite of having higher canal irrigation (>80%). LQ is under 0.3-0.6 in Memari- I and II Blocks because potato is

cultivated in 26% and 9% of GCA in these blocks. Again, Galsi - I and Bhataris categorized under 0.3-0.6 due to sharing of 33% and 11% of GCA in*boro*. LQ of 0.6-0.9 is noticed in Monteswar, Burdwan -II, Raina -II and Kalna- II. LQ of higher than district's average(1.2-1.5) is in Galsi - II, Ausgram -I, Burdwan- I, Mangolkote, and Ketugram - II. Katwa -I, and Purbasthali-I Blockare under LQ 1.5-1.8 where in 37% and 38% of GCA are cultivated in *boro*. Exceptionally, in Faridpur-Durgapur, LQ is 3.3-3.6 which is 3.5 times of district's concentration of *boro* (Map No.3).

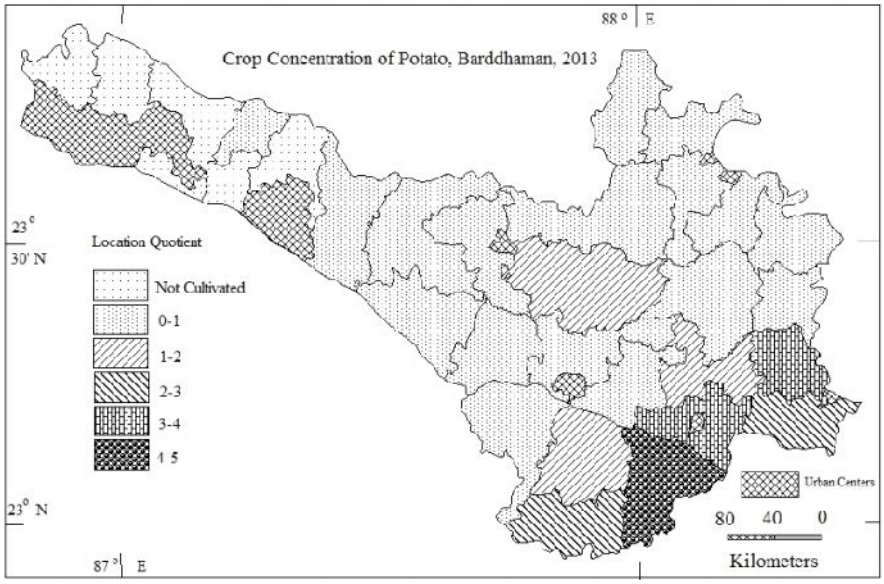


Map No.3: Crop Concentration in *Boro*, Barddhaman, 2013

3.4. Crop Concentration of Potato

Cultivation of potato is confined mainly in south-eastern part of the district. In general, soil texture (mainly coarse texture) controls the cultivation of potato through water holding capacity, compactness and air-water circulation. Potato is not cultivated in Salanpur, Barabani, Jamuria, Pandabeswar, Raniganj, and Faridpur-Durgapur (19.6% of land). In Barddhaman, sharing of GCA in potato is 8%. Mangolkote, Ketugram -I, II, Katwa-I, II, Purbasthali-I, and II are categorized in the lowest LQ of 0-1 which is lower than average of the district. In Bhatar, Memari-II, and Raina- I, the LQ value is 1-2 which is double than the district's average. In Raina II, potato is cultivated three times of (LQ 2-3) district's average. Memari- I and Kalna- I are categorized under

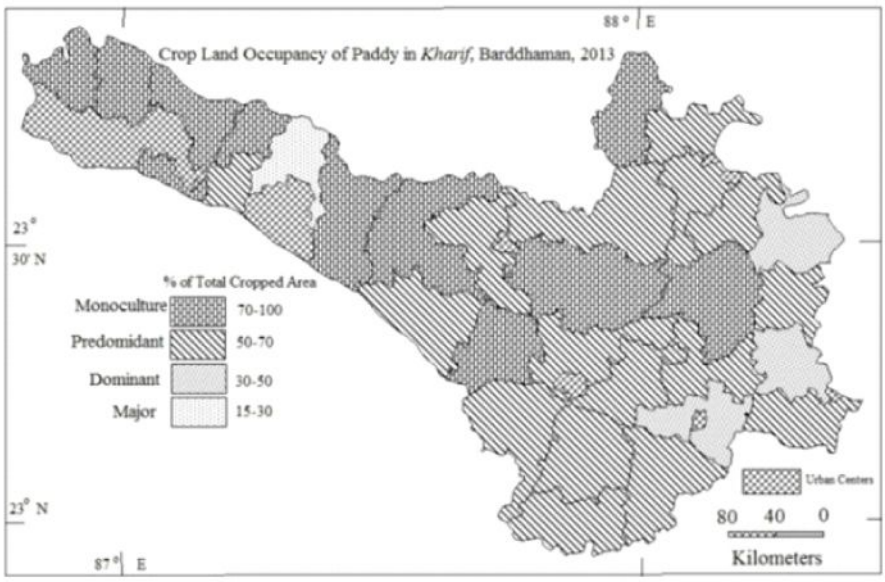
LQ of 3-4 where 26% and 30% of GCA are under potato cultivation. In Jamalpur, the LQ of concentration of potato is 4-5 which is five times of district's average because 38% of GCA is used for cultivation of potato using groundwater (Map No.4).



Map No.4: Crop Concentration, Barddhaman, 2013

3.5 Crop Land Occupancy of Paddy in *Kharif* Season

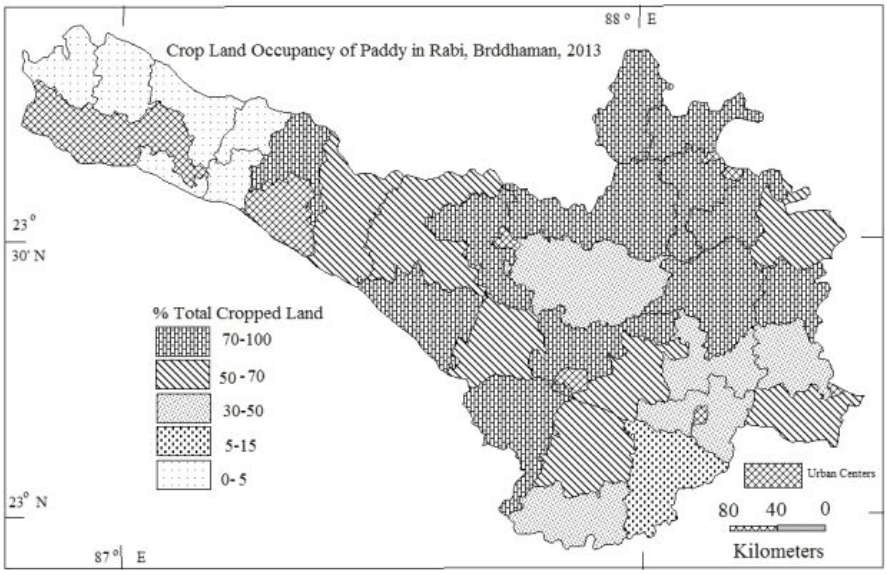
This is an indicator for assessing the percentage of land in a particular crop and more than 70% of crop land occupancy is called monoculture. In Salanpur, Barabani, Jamuria, Pandabeswar, and Raniganj Block, *aman* is cultivated in 100% of GCA. So, there is monoculture in *kharif* season. Again, in 36.73% area of the district, monoculture is also practiced in Kanksa, Ausgram - II, Galsi - II, Bhatar, Monteswar, and Ketugram - I. Predominant category (50-70%) is foundin Galsi - I, Ausgram- I, Mangolkote, Katwa-I, II, Ketugram - II, Burdwan- I, II, Memari - II, Khandoghosh, Raina - I, II, Jamalpur and Kalna- II. Memari - I, Kalna- I, and Purbasthali- II are identified as dominant land occupancy (30-50% of GCA). Major land occupancy (15-60%) in *kharif* has been noticed in Faridpur-Durgapur (Map No.5). The occupancy of crop land of paddy is negatively related with diversification of crops ($r=0.6797$, $p=<0.01$).



Map No. 5: Crop Land Occupancy of *Aman* Paddy in *Kharif*, Barddhaman, 2013

3.5. Land Occupancy of *Boro* Paddy

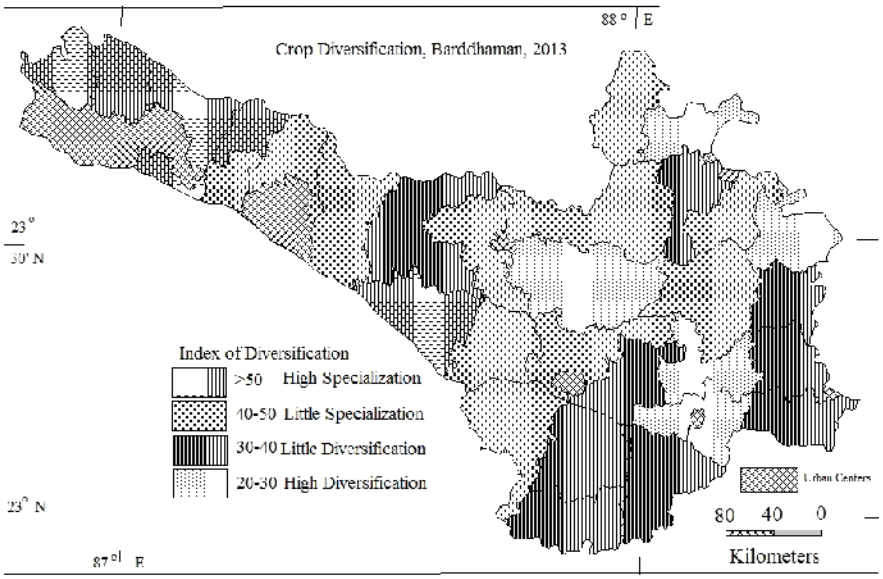
This is an index showing the sharing of area of paddy in *rabi* season. In this season, paddy is not cultivated in Salanpur, Barabani, Jamuria, Raniganj, Pandabeswer, and Andal. In Jamalpur, secondary land occupancy (5-15% land) has been observed in *boro*. Dominant category (30-50% of NSA in *rabi*) is noticed in Raina- II, Memari- I, II, Kalna-I, and Bhatar due to predominance canal irrigation. Predominant category (70-50%) has been observed in Kanksa, Ausgram - II, Raina- I, Burdwan- II, Kalna- II, and Purbasthali-II. Monoculture is practiced in 41.03% land of Galsi-I, Ausgram-I, Burdwan- I, Khandoghosh, Manteswar, Ketugram - I, II, Katwa-I, II, Purbasthali-I, and Faridpur-Durgapur (Map No.6). The crop land of *boro*is positively related with canal irrigation ($r=0.3082$, $p=<0.1$).



Map No. 6: Crop Land Occupancy of *Boro* Paddy, Barddhaman, 2013

3.6. Diversification of Crops

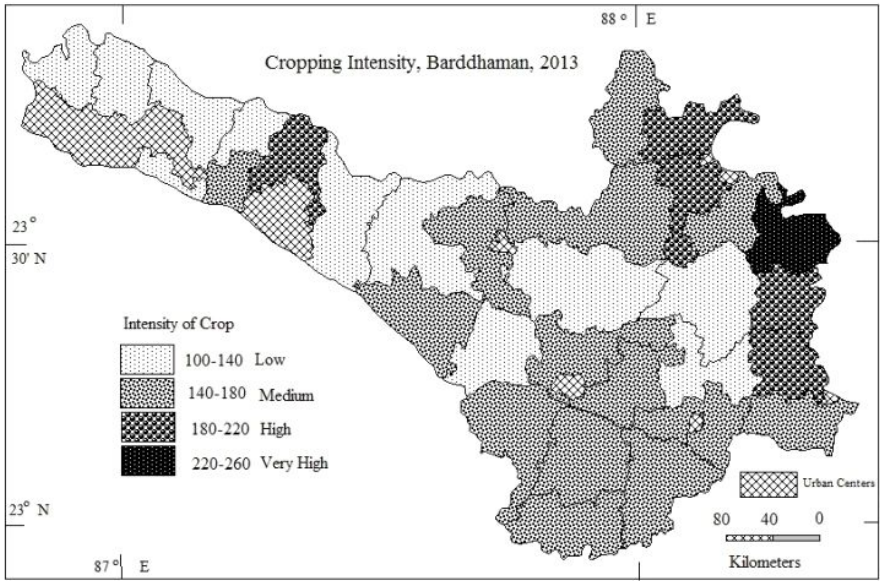
Generally, Barddhamanis specialized in cultivation of paddy but there is an inter-block difference in the diversification or specialization of crops. The specialization (>50) is highest in Salanpur, Barabani, Jamuria and Pandabeswar where only *aman* is cultivated. The little specialization (40-50) has been observed in 35.48% land of Kanksa, Andal, Faridpur-Durgapur, Ausgram-I, Mangolkote, Ketugram - I, Katwa- II, Manteswar, Burdwan-I, Galsi-II, and Khandoghosh. Little diversification index (30-40) is found in Ausgram-II, Raina- I, II, Jamalpur, Burdwan-II, Purbasthali-I Kalna- I, II, Katwa- I wherein three crops are cultivated. High diversification index (20-30) has been obtained in Bhatar, Memari-I, II, Ketugram - II, and Purbasthali-II (18% area) where four crops are cultivated. Highest diversification is observed in Purbasthali-II (22.8) due to sharing of 95% of GCA in groundwater (Map No.7). So, in these four blocks, cultivation of crops is most diversified and shown suitable for multi-crops in a crop calendar.



Map No. 7: Crop Diversification, Barddhaman, 2013

3.7. Cropping Intensity

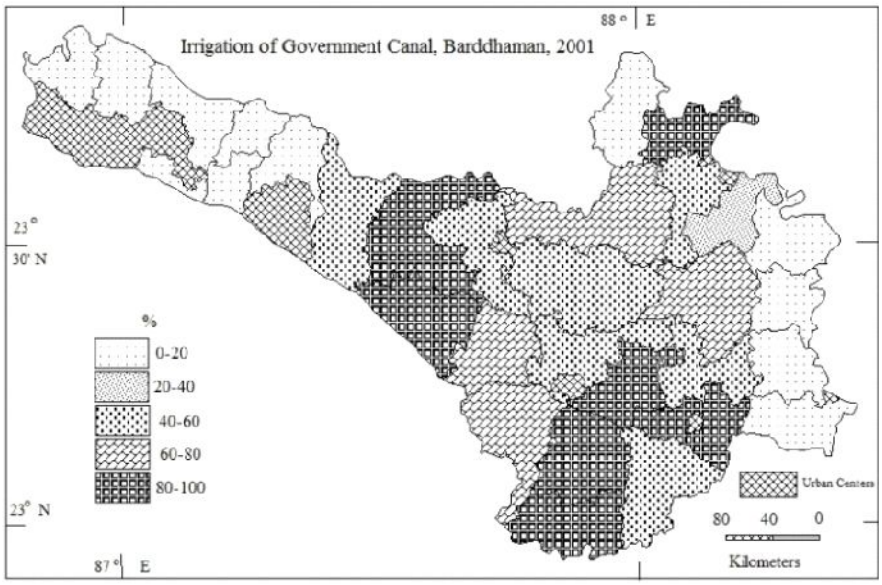
This is the index to show the multiple use of agricultural land in different crops. The cropping intensity is lowest (100) in Salanpur, Barabani, Jamuria, and Raniganj where only *aman* crop is cultivated. But low intensity of crops (100-140) is found in Pandabeswar, Kanksa, Ausgram - II, Galsi - II, Bhatar, Manteswar and Memari -II due to unavailability of canal irrigation as well as groundwater irrigation (<25% land). The correlation between canal irrigation and cropping intensity is negative (r=-0.118, p=>0.1). Medium cropping intensity (140-180) has been found in Galsi - I, Ausgram -I, Mangolkote, Ketugram - I, Khandoghosh, Raina- I, II, Burdwan -I, II, Memari- I, Jamalpur and Kalna-II where >50% irrigation comes from government canal (GC) and these blocks are specialized for *aman* and *boro*. High cropping intensity (180-200) is noticed in Faridpur-Durgapur, Ketugram - II, Katwa- I, Purbasthali- I, Kalna I because of higher irrigation facility (>40% of irrigated land). Purbasthali-II has been categorized under very high cropping intensity (200-260) due to intensive ground water irrigation facility (>90% NSA) (Map No.8).



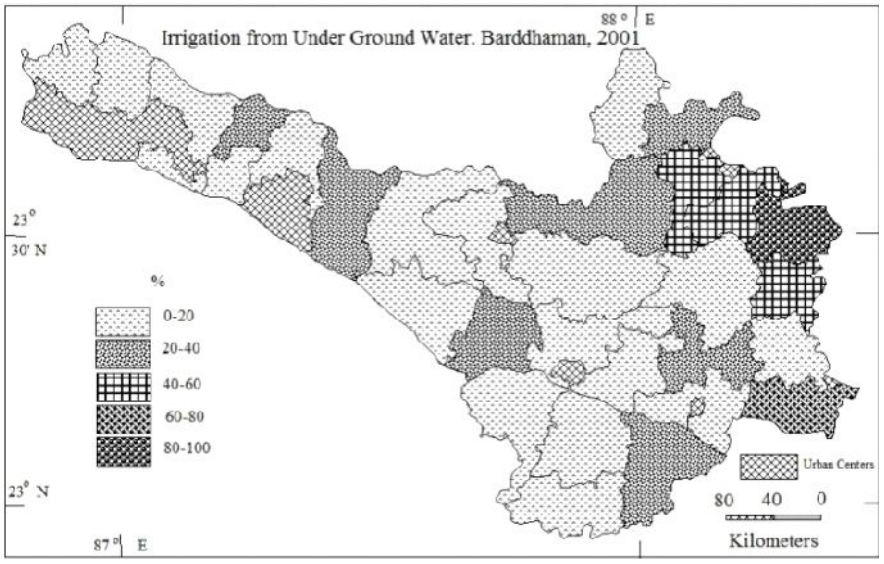
Map No.8: Cropping Intensity, Barddhaman, 2013

3.8. Sharing of Canal Irrigation

The water of Damodar is diverted into canal to irrigate the crop lands in Barddhaman District. But the sharing of canal irrigation is not uniform. In Salanpur, Barabani, Jamuria, Pandabeswar, Raniganj, Andal, Faridpur-Durgapur in the west and Purbasthali-I, II, Kalna- I, and II in the east of the district, less than 20% of NSA is under canal irrigation. In the east, establishment of canal is not possible for intense river system (tributary of River Ganges). In Kanksa and Katwa- II, 20-40% land comes under canal irrigation. In Jamalpur, Burdwan- I, Memari -II, Bhatar, Ausgram- I, and Katwa -I, 40-60% of total irrigated land is served by canal. In Khandoghosh, Galsi - II, Manteswar, and Mangolkote, canal (GC)serves 60-80% of total irrigated land. The highest sharing of GC irrigation (80-100) has been found in Raina -I, II, Burdwan- II, Memari- I,Ketugram - II, Ausgram - II and Galsi - I where left bank main canal, Damodar main canal, and Eden canal serve water for irrigation in arable land (Map No.9).



Map No. 9: Irrigation of Government Canal, Barddhaman, 2001



Map No.10: Irrigation of Ground Water, Barddhaman, 2001

3.9. Groundwater Irrigation

Well, with electric connection, and tube well with or without electric connection have been considered as source of groundwater for irrigation. The lowest ground water irrigation (<20%) is found in 63.54% area of the district. In Mangolkote, Ketugram - II, Memari -II, Jamalpur,Galsi - II, Kanksa, and Pandabeswar, 20-40% land is under groundwater irrigation. In Kalna-II and Purbasthali -II, 60-80% and 80-100% of land are irrigated with groundwater respectively (Map No.10). So, in eastern part of the district where establishment of canal is not possible, groundwater is an alternative source of irrigation.

4.0. Discussion

4.1. Factors of Crop Combination

Crop combination of the district is controlled with soil health (r=0.4837, p=<0.01) and irrigation facility (r=0.4245, p=<0.05) (Fig. No. 1&2). Lateritic soil and low nutrient content in western part of the district leads to single crop combination.

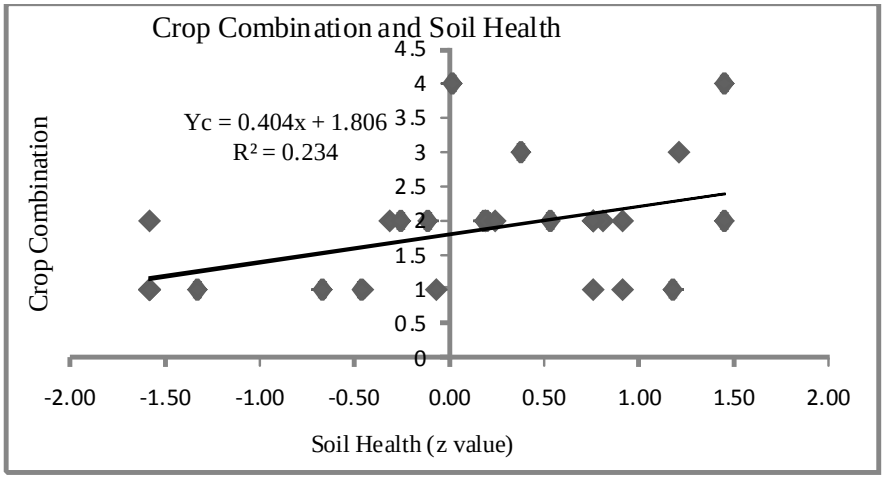


Fig. No. 1: Crop Combination and Soil Health

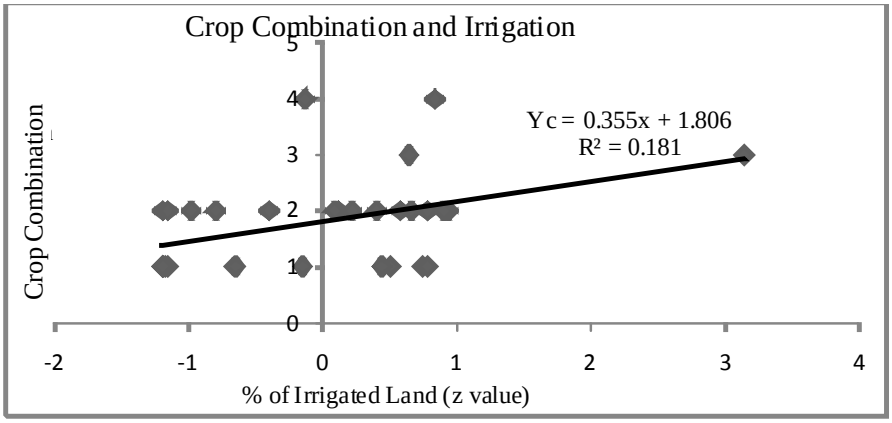


Fig. No.2: Crop Combination and Irrigation

Multiple regression has been calculated for combination of crop (CC) with soil health (SH), irrigation facility (IR) and diversification of crops (D). The equation is CC= 1.80662+0.194 × SH + 0.1393 × IR-0.2027 ×D, r=0.5488, R=0.3012, p=0.0198.

Highest coefficient value has been found in diversification of crops (r=0.48, p=<0.01). The correlation value of multiple regression (r=0.5488, p=0.0198) is explained with 30.12 per cent of variance of crop combination (Fig. No. 3). Positive residuals has been found in Memari -I, Purbasthali -II, Kalna- II, Raina- II and Andal where small land holding, high agricultural density and irrigation facility in *rabi* are the factors of multiple crop combination. Again, negative residual has been found in Bhatar, Manteswar, Galsi - II, Memari -II, Ausgram - II and Kanksa where unorganized market facility for *rabi* crops and or canal irrigation may restrict the cultivation in *aman*.

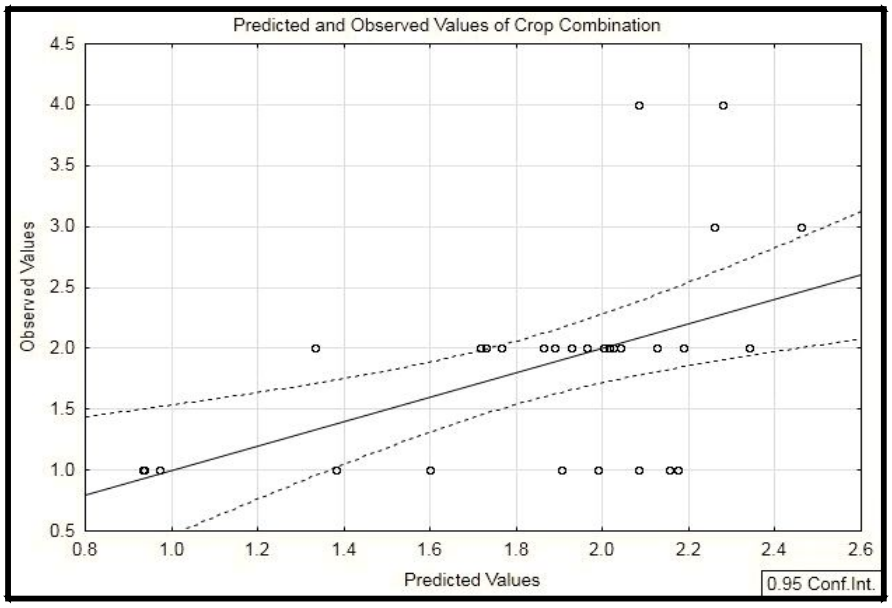


Fig. No 3: Predicted and Observed Values of Crop Combination

4.2. Crop Diversification and Irrigation of GroundWater

The signified positive correlation has been found between diversification of crops and use of groundwater (r=0.411, p=<0.05) (Fig. No.4). The use of groundwater, regulated as well as judicious use and or minimum loss of water, are the ways for higher potentiality of irrigation to cultivate different types of crops according to fertility of soil rather than cultivation of mono crop which inturn leads to minimize risk in agro-ecosystem and soil fertility.

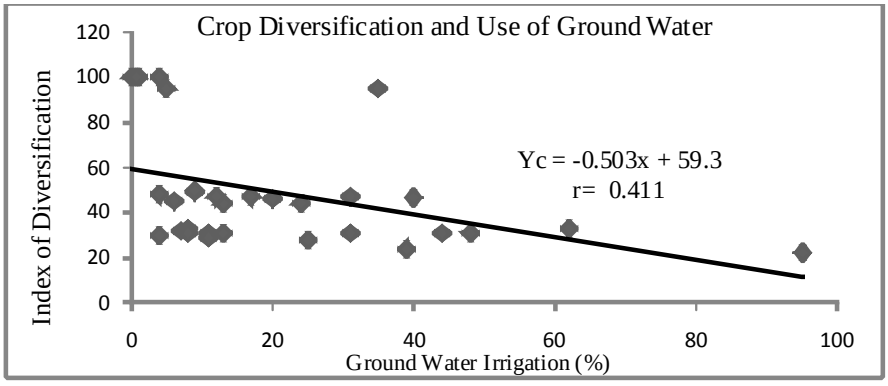


Fig. No. 4: Crop Diversification and Use of Ground Water

4.3. Cropping Intensity and Irrigation Facility

The correlation between cropping intensity and canal irrigation (-0.118, p=>0.1) is not satisfactorily signified for enhancing potential as well as multiple use of agricultural land in Barddhaman. The correlation between cropping intensity and use of groundwater irrigation is signified at 99% level (r=0.5329, p=<0.01) because farmers can cultivate different types of crops as per their requirement using groundwater (Fig. No.5 and 6).Alternatively, farmers generally follow the supply of water from DVC and they are compelled to cultivate paddy. But without the supply of canal water (like as *aman* cultivation in 2015), the production and agricultural system may be collapsed. Higher cropping intensity is also increased with increasing diversification of crop (r=0.1581, p=>0.1) (Fig. No.7).

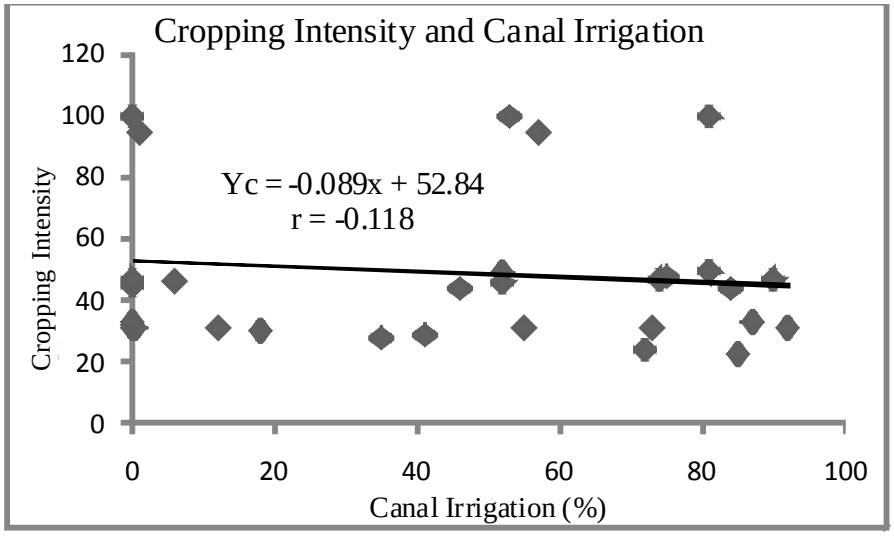


Fig. No. 5: Cropping Intensity and Canal Irrigation

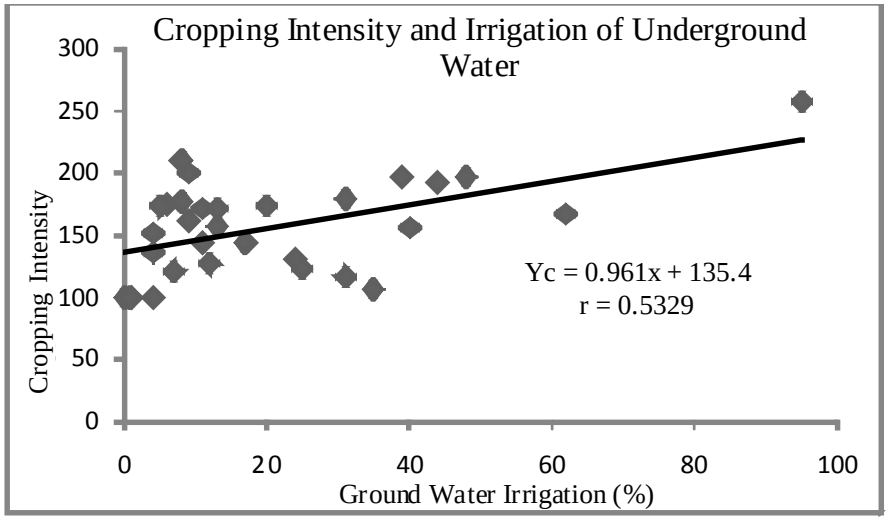


Fig. No. 6: Cropping Intensity and Irrigation of Ground Water

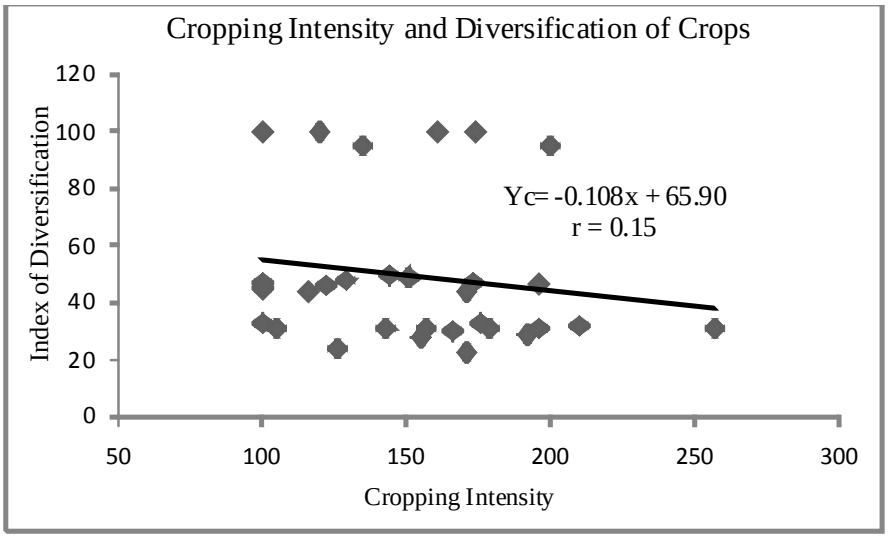


Fig. No. 7: Canal Irrigation and Crop Land Occupancy in *Boro*

5.0. Conclusion

From this investigation, soil health and irrigation have been found as dominant factors of the crop combination. More than 70% of cultivable land is used for mono crop cultivation. Diversified crops are practiced in Memari-I and

Purbasthali- II using ground water irrigation and in Jamalpur, Memari-I, and Kalna-I, potato is the main crop. As crop rotation and diversification improve stability of production, soil fertility and agro-economic scenario, diversified combination of crop is to be practiced in Barddhaman to avoid unprecedented negative effects on agriculture as in Punjab after green revolution.

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