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Criticality Assessment in Agricultural Environment with Varying Level of Intensification – A Study in Nayagram Block of West Medinipur, West Bengal

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Abstract: *To fulfill the dream of providing food to all, pressure on agricultural field are increasing day by day. Despite several flaws our farmers still follow the foot print of Green Revolution for increasing the level of agricultural intensification. Often the intensification of agricultural practices done by some unplanned anthropogenic interference like, application of chemical manure, use of pesticide and insecticide, exploitation of ground water, expansion of agricultural area, method of cropping etc. leads to serious criticality in agricultural environment. Such type of assessment not only helps to understand the dynamic relation between agricultural intensification and environment but also to identify the level of criticality set by internal agricultural practice. A study was carried out in Nayagram block of West Medinipur district, West Bengal by dividing the area into three distinct zones as per apposite agricultural density (AAD), 2010 - 2011. For the delineation of apposite agricultural area, an agricultural suitability map (ASM) has been prepared from Landsat TM satellite image by the assimilation of Indices based digital image processing (DIP) and weighted overlay analysis. A study was undertaken with interview based acquired data on agricultural intensification parameters to find out the present level of criticality in agricultural environment. From the ASM, total suitable agricultural area of the block was estimated as 297.365 Km.^{2}. Parameters of agricultural intensification were found more threatening to environment with increasing level of apposite agricultural density (AAD). Thus the work transmits immense potentiality for proper assessment of criticality in agricultural environment.*

Keywords - *Apposite agricultural density (AAD), agriculture suitability map (ASM), DIP, intensification, criticality*

I. Introduction

The United Nations University quoted the term environmental criticality as situations in which the extent and rate of environmental degradation preclude the continuation of current human use system. In agricultural sector the importance of assessing environmental criticality is getting prioritized as modern agricultural practices are putting enormous pressure on environment. The availability of per capita arable land in India has decreased alarmingly from 0.34 hectares in 1951 to 0.17 hectares in 2001 (Sharma & Ram, 2009) [1]. Despite such downward trend, national food production has increased 21.832 % during the economic year 2001-2002 to 2011 – 2012 to reach all time high as 259.32 million ton (The Hindu, 11 May, 2013). Such an outstanding performance will no doubt help the country to achieve the dream of universal food security, but of course giving birth to a serious question - are the agricultural environment is getting more critical with the increasing level of agricultural intensification?

It is an established thought that level of agricultural intensification is directly related with pressure of population on agricultural sector. More intense agriculture is the demand of more dense population. Conventionally, population pressure on cultivated area was estimated by means of agricultural density. However such type approach does not bring consideration of areas having potentialities of agricultural practice but not in use presently. Hence in the present work the concept of Agricultural density was replaced by Apposite Agricultural density (AAD). Emphasized were given on identifying agricultural suitable area with the help of integrated studies using indices based digital image processing and GIS application. Application of such operation to digital image improves the visual appearances for better interpretability and subsequent digital analysis (Lilliesand and Kiefer, 1999) [2].

The study of criticality assessment in agricultural environment has laid its foundation by analysing some unplanned anthropogenic interference like, application of chemical manure, use of pesticide and insecticide, exploitation of ground water, expansion of agricultural area, method of cropping, etc. Analysis of parameters helps to reveal the individual parameter wise criticality level in agricultural environment with varying level of intensification. Finally overall criticality in agricultural environment has been drawn by the integration of results obtained from all the parameters. Thus the study is set to assess the overall criticality in agricultural environment as well as to find the relation between population pressure and agricultural environmental criticality.

II. Study Area

Nayagram, having an area of 501.44Km2, located in south western part of West Medinipur district of West Bengal state, bounded by 22 o 44/ N to 22 o 74/ N latitude and 88 o 08 / E to 88 o 13 / E longitude has been selected for on-going research rationale (Figure 1). It is a community development block under Jhargram subdivision. The area is unique for its undulating topography, lateritic soil and natural forest with predominating species of Sal and Mahua tree.

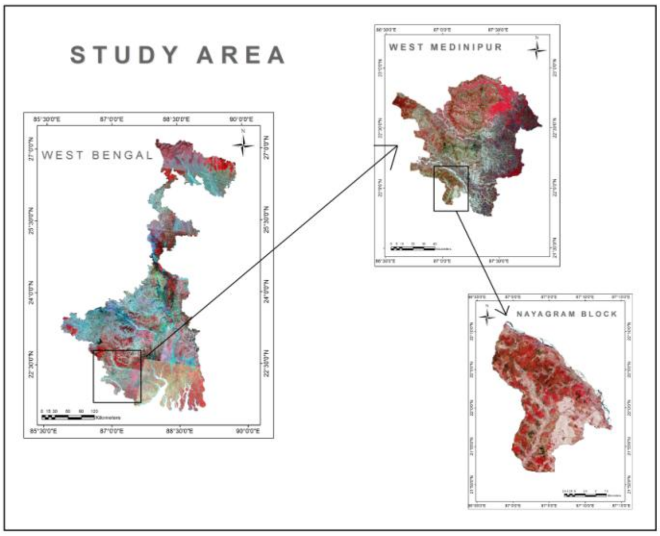

Fig. 1 Location of the selected area

The selected study area has a total population of 1, 42,199 among which around 40 % are tribal population (Census of India, 2011). Agriculture is the main livelihood of the people having a gross cropped area of 29,550 ha. Paddy is the staple crop whereas sugarcane and rope making grass were cultivated as cash crop. Due to scarcity of water and sandy infertile soil, large spread backwardness in terms of agricultural activity has been prevailed over the years.

III. Data And Software Used

In the present study Landsat satellite images for the month of February covering the selected area were used and processed under TNT Mips Pro 2013 and ARC GIS 10.1 environment. The specifications of the products are described in table 1.

Table 1: Description of satellite data

Landsat TM Digital image	WOID - L5010471	Path / Row	139 / 45
		Date of acquired	13.02.2010
		Resolution	30 m.

Primary data was collected through an extensive interview during the period May – June, 2015 keeping in mind different parameters responsible for bringing criticality in agricultural environment. Secondary data was also consulted which was obtained from local agricultural office.

IV. Methodology

In first phase, selected study area was categorized into three distinct zones, high, moderate and low in terms of population pressure on agriculture suitable area. For this apposite agricultural density (AAD) index has been used which was a derivation of agricultural density index. The calculation of AAD was done at gram panchyat (GP) level by the ratio of total population and agriculture suitable area. Total population of each GP was collected from census data 2011.

To delineate the agriculture suitable area, an integrated approach of indices based digital data processing and weighted overlay analysis was conducted (Moyra & Hazra 2016) [3]. Researcher commonly used general image classification for the discrimination of area of interest from the satellite image (Rees 2001) [4]. More advance studies also used indices approach to distinguish cropped area from satellite images (Bannari,

1995) [5]. NDVI, SAVI, TSAVI are some renowned vegetation index which are frequently used in this regard for their high sensitiveness to vegetation.

However, deriving agricultural suitable area with such mentioned approaches are bound to suffer from lack of accuracy as spectral reflectance of dense vegetation and cropping land are very close in nature like in the case of present study(Choudhury1987) [6]. To mitigate such challenges, a multi criteria decision making (MCDM) approach based overlay analysis of tasseled cap derivation has been developed in this regard. By this an agricultural suitability map (ASM) of the study area was prepared. The tasseled cap transformation provides excellent information for agricultural applications because it allows the separation of barren soil from vegetated and wet soils (Thompson 1980) [7].

A multi parametric dataset resulted from tasselled cap transformation of Landsat satellite image, i.e. Greenness, Brightness and Wetness have been integrated under multi criteria analysis (MCA) providing equal weight i.e. 33.33% (Wi) to each parameter. Individual dataset were classified into five categories and assigned with sub weight (Xi) within the range 1to 5. Sub weight has been set for each class based on their internal capacity to support agricultural practice. Such interdisciplinary data was combined with weighted linear combination (WLC). In WLC the total score (Si) for each alternative was obtained by multiplying the importance weight assigned to each parameter (Wi) by the feature score (Xi) and then summing the products overall attributes as Si = [Wi * Xi] (Moyra, Hazra& Roy 2014) [8].

Table 2: Selection of weight and sub weight

Dataset	Wi	Value	Identified Feature	Xi
Greenness Index	33.33	-30.30 - -8.91	Water	1
		-8.91 - -0.86	Agricultural Fallow Land	4
		-0.86 - 3.66	Agricultural Crop Land	5
		3.66 - 9.20	Degraded Forest	2
		9.20 - 33.86	Dense Forest	1
Brightness Index	33.33	0 - 125.74	Dense Forest	1
		125.7 - 148.0	Degraded Forest	1
		148.0 - 174.7	Agricultural Land	5
		174.7 - 220.3	Agricultural Fallow Land	4
		220.3 – 283.7	Sand Deposit	4
Wetness Index	33.33	-251.4 - -77.1	Sand Deposit	3
		-77.11- -53.3	Agricultural Land	5
		-53.39 - -35.6	Degraded Forest	1
		-35.6 - -10.70	Dense Forest	1
		-10.70 - 50.9	Water	1

By the help of Saaty's Eigenvector method, consistency of the each sub weight set is determined. Cconsistency ratio (Cr), indicator for errors in judgment was calculated (Satty 1980) [9] by the help of formula 1.

$$Cr = [Ci * Ri] \qquad (1)$$

(Where Ci represents Consistency index, which is calculated with web based calculator and Ri stands for Random index, a composite of two different experiments performed by Satty at the University of Pennsylvania has the value of 0.5 for 3 observations.)

In the second phase criticality in agricultural environment has been explored on the basis of in-depth study of five selected agricultural intensification practices in three AAD zone. Practices like, application of chemical manure, use of pesticide, exploitation of ground water, expansion of agricultural area and method of cropping were studied. Individual contribution of each parameter as well as overall contribution of all parameters in making agricultural environment critical has been measured by indexing and ranking approach respectively.

Farmers use fertilizer in order to boost the agricultural production without much of putting serious thought about its reaction with agricultural environment. For the assessment of fertilizer criticality in agricultural environment, fertilizer criticality or Fc index has been developed. This index has been developed depending on acquired field data in different aspects of fertilizer application. While developing this index, algebraic operation was organised in such a way that it would give higher lever of criticality value with increasing level on stress in agricultural environment. Fc can be calculated as:

$$Fc = [(Ach / 100) + \{(Pur / Rch\text{-}or) * K\}] \qquad (2)$$

(Where, Ach = Amount of chemical fertilizer applied in Kg. per ha, Pur = % of urea to total chemical fertilizer, Rch-or = Ratio between chemical and organic manure and K = Average no. of farmer applied micronutrient without testing the soil or expert suggestion.)

Like fertilizer farmers also use various chemical sprays to protect their crop from pests and diseases. Application of such matter often endangers the agricultural environment. By developing a pesticide criticality or Pc index, criticality level of pesticide application has been assessed. Though we have used the popular term pesticide, it also includes insecticides and fungicides. Pc can be calculated as

$$Pc = [(Npe * Vpe) * K] \quad (3)$$

(Where, Npe = Average no. of times pesticide applied in major crop, Vpe = Average variety of pesticide used and K = Average no. of farmer found having no knowledge of distinguishing pesticide and fungicide.)

Rain water is not so reliable in situations where the crop are grown facing the climatic challenges. In such case irrigation helps to avoid crop failure as well increase crop intensity. In spite of its goodness extensive irrigational activity put pressure on agricultural environment. As per source of irrigation, subsurface source is more critical than surface. Depending on this theme an irrigational criticality or Ic index has been prepared as under

$$Ic = [(Acu / Air) * (Ass / Asu)] \quad (4)$$

(Where, Acu = Total cultivated area during a year, Air = Total irrigated area, Ass = Area irrigated by sub surface source and Asu = Area irrigated by surface source)

The arrangement of agricultural field develops marked variations in individual criticality level. Agricultural land type of the area is found as upland, middle land and low land. Among this category, upland agricultural activity is considered as most critical for the environment. By utilizing the agricultural land type information a land criticality index or Lc has been formulated.

$$Lc = [(Aup / Acu) * 100] \quad (5)$$

(Where, Aup = Cultivated upland area and Acu = Total cultivated area during a year)

There are several indices present for measuring the cropping intensity. Among them being the simplest and universally accepted, multiple cropping index (MCI) has been selected for the present study. MCI actually measures the cropping intensity, i.e., how many crops are grown in a selected land within a year (Dalrymple, 1971) [10]. Following is the details of the computation of cropping intensity criticality index or CIc

$$CIc = [(Ai3/ Acu) * 100] \quad (6)$$

(Where, Ai3 = Area occupied by the all crop and Acu = Total cultivated area during a year)

Overall criticality assessment in agricultural environment is essential for studying the sustainability of an agricultural system. On the basis of five criticality parameters, overall criticality value of three apposite agricultural density (AAD) zone has been acquired. Then the AAD zones were provided marks based on their parameter wise criticality value level. Highest criticality was given 1; 0.5was set for moderate criticality and 0.1 was given to lowest criticality. Thus each AAD zone obtained 5 separate criticality marks regarding different parameters with probability of obtaining highest marks of 5.

V. Result And Discussion

At first result of Greenness, Brightness and Wetness prepared by tasselled cap transformation as shown in figure 2 has been studied. In general the range of Greenness was found between -30.30- 33.86. Highest greenness class was associated with forest vegetation, whereas lowest vegetation denotes bareness condition of surface. The range of Brightness was found between 0.0 - 283.7. Highest brightness class was found in sand deposit. With increasing brightness cultivable land gets sandy texture. Wetness have range between -251.4 - 50.9. In shallow and marshy land highest wetness class was found and it was lowest in sand.

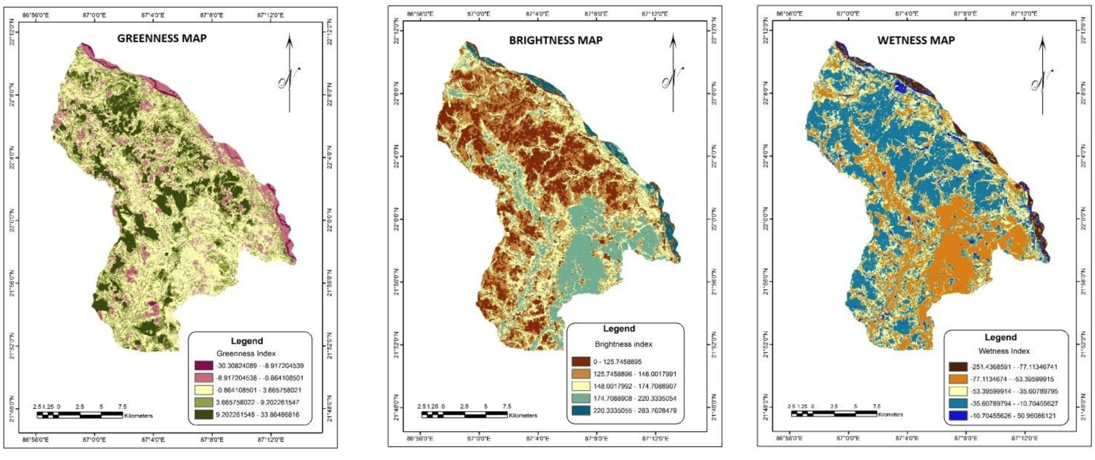

Fig. 2 Greenness, Brightness and Wetness map

It was found that moderate greenness was associated with agricultural tracts (-8.91-3.66). In case of wetness second lowest class was identified as agricultural area having value -77.11- -53.3. Again third and fourth highest class (148.0-220.3) of brightness index has been selected as agricultural suitable area. Condition of Greenness, Brightness and Wetness information is dynamic in nature. In the study it was normalized by gathering information from image of same season. As the study was conducted on the basis of Ravi season image, hence the agricultural field were found semi green, poorly wet and highly bright.

From the result of weighted overlay analysis agricultural suitability map (Fig. 3) has been prepared. In the present study, determination of agricultural suitable area is done by the process of reclassifying the result of overlay analysis. The map has been broadly categorized into segments, i.e. suitable agricultural area and non-suitable agricultural area. The total suitable agricultural area was assumed as 297.365 Km.2.

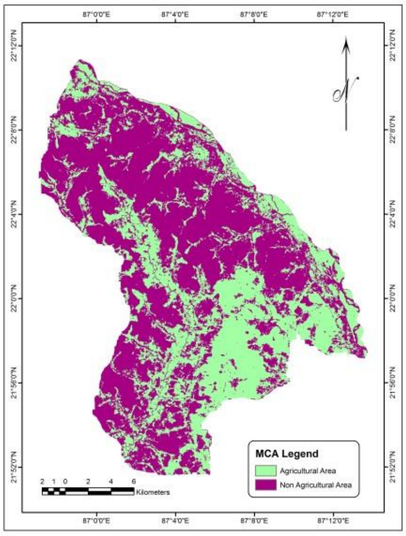

Fig. 3 Agricultural suitability map

Accuracy of the combination between Greenness, Wetness and Brightness was determined in order to increase the reliability of result. The value of   is found within accepted level i.e. less than or equal to 0.1.Cr for Greenness, Wetness and Brightness were found as 0.031, 0.072 and 0.066 respectively.Depending on the value of AAD, 12 GP of Nayagram block has been classified into three AAD zones having equal no of representation. Nayagram, Kharikamathani, Malam, Barakhankri was classified as high AAD zone having value of > 635. Patina, Chandabila, Chandrarekha, Arrah was represented by moderate AAD class with value 500 – 635. Baranegui, Baligeria, Berajal, Jamirapal was classified as low AAD zone having value of > 500.

In depth study of manure application suggests that chemical fertilizer application was found highest in high AAD zone with value 70.62 Kg per hectare in major crop while organic manure was more applied in moderate AAD zone. Chemical criticality was found highest in high AAD zone and lowest in moderate AAD zone. No. of time pesticide used in major crop was found highest in moderate AAD zone having value of 1.875, whereas variety of pesticide application was found highest in low AAD zone. In terms of pesticide criticality the lowest AAD zone secured top position. Like chemical criticality, pesticide criticality was also found lowest in moderate AAD zone (figure 4).

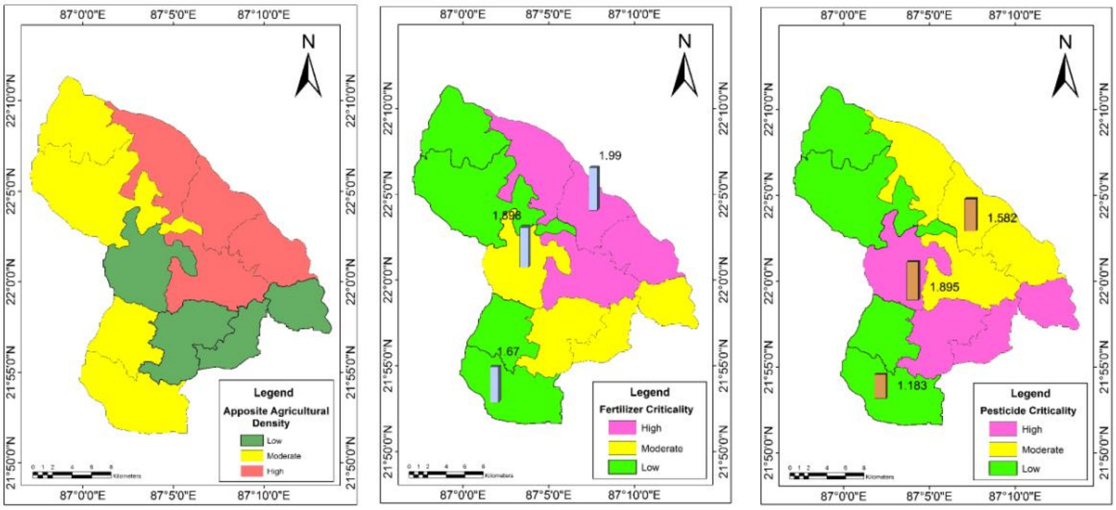

Fig. 4 AAD, Fertilizer criticality and Pesticide criticality map

By studying the several criteria used to determine irrigational criticality it was found that expansion of irrigation has positive relation with AAD. Results of irrigational criticality suggest that zone with highest AAD suffers from highest irrigational criticality and criticality tends to minimize with decreasing level of AAD as shown in figure 5. Cultivation on upland or locally called Dahi Jami was also increases the criticality in agriculture environment. Such cultivation triggers the soil loss process as well as encourages deforestation. Land criticality was measured in percent value and it was found highest in moderate AAD zone. With increasing level of intensity agricultural land gets little chance to recover health. Intensity criticality index which was calculated in percent, showed highest criticality value in high AAD zone.

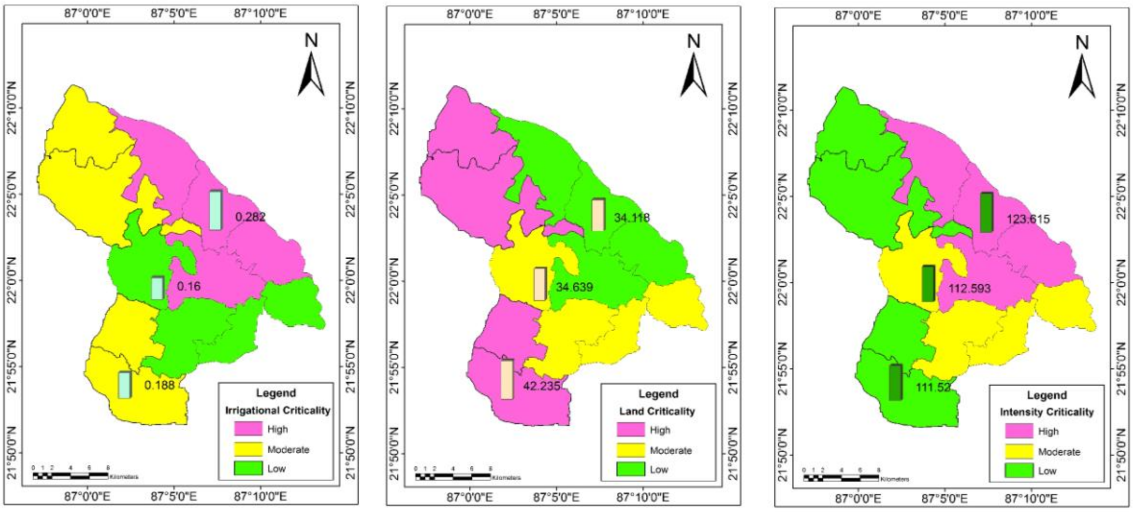

Fig. 5 Irrigational criticality, Land criticality and Intensity criticality map

The overall criticality score for each AAD zone was computed with the help of table no. 3. From the table it is explored that highest criticality in agricultural environment was found in high AAD zone having value of 3.6. Surprisingly moderate criticality score (2.6) was shown in low AAD zone, whereas low criticality score (1.8) was associated with moderate AAD zone.

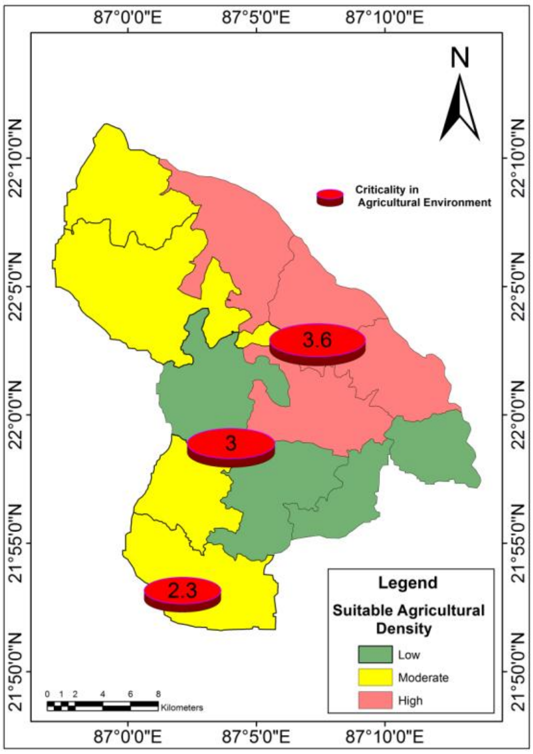

Fig. 6 Overall criticality in agricultural environment

It is generally believed that population pressure is the main reason behind the increasing level of criticality in agricultural environment. Our study reveals that it is not always true. As the findings of present study shows that zone with low population pressure have make their agricultural practices more critical than the zone with comparatively high population pressure. From the view point of favorable agro setup, the low AAD zone is most adverse in nature. To complement it farmers of this zone used to apply more agricultural input which ultimately increases the vulnerability of the environment.

Table 3: Overall criticality score

AAD zone	Fc	Pc	Ic	Lc	CIc	Criticality score
High	1	0.5	1	0.1	1	3.6
Moderate	0.1	0.1	0.5	1	0.1	1.8
Low	0.5	1	0.1	0.5	0.5	2.6

VI. Conclusion

Overall analysis of our study explore that criticality in agricultural environment of the study area varies with the level of intensification. But not all the time criticality is positively related with population pressure on agricultural land. Human behaviour, absence of government intervention and impact of market have made the relation complicated. Nevertheless man has to follow the natural limit set by environment. Violation of such limit would bring disaster to modern civilization.

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