Mapping Suitable Areas for Growing Pulses in Rice-Fallows using Multi-Criteria Spatial Decisions

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ABSTRACT

Food legumes (Pulses) play an important role in ensuring food and nutritional as well environmental security through crop diversification and sustainable intensification in India and elsewhere. India imports nearly 4-5 million tons annually to meet its domestic demand. There is a need to increase both productivity and production to bridge the supply-demand gap and one such opportunity lies in the potential use of crop-fallows such as rice-fallows. The rice fields in eastern and central India remain fallow after the main crop harvested. Limiting factors are the lack of understanding of the fallow dynamics, soil moisture regimes and unavailability of suitable crops and crop varieties, etc. Therefore, a pilot study has been undertaken to map and quantify suitable areas for growing short duration pulses (lentil, grasspea and chickpea) in rice-fallows of West Bengal region. Rice area, fallow area and associated vegetation and crop phenological parameters such as: start and end of fallow periods, length of the fallow periods, etc. were used for assessing the rice-fallow dynamics across the growing seasons and years. The resultant outputs were further analysed in geostatistical domain with various causative factors to determine suitable range and resultant values were normalized with fuzzy-gamma function to produce hotspot index values. The suitability assessment used 16 factors as suitability parameters, including climatic conditions, soil types, soil moisture, nutrient characters, topography data. The fuzzy-set model with analytic hierarchy process (AHP), Multi-Criteria Decision Making (MCDM) and GIS technique were integrated to create final lentil suitability map. The preliminary results showed that nearly 61% of the analysed area are suitable for growing lentil in range of most suitable (21%) to moderately suitable (40%) followed by marginal (19%) to least suitable (18%) for lentil production. The map and zonal stats were verified with national statistical data available at district level. This is ongoing study, it needs further analysis to quantify dynamics of suitability across the years, rainfall pattern, socio-economic and ecological aspects to develop user-friendly-interactive decision making tool for sustainable intensification and crop diversification in the rice-fallows.

Keywords: Mapping, Suitablity, Lentil, Pulses, Rice fallows, AHP, MCDM

INTRODUCTION

- The rice fields in eastern and central India remain fallow after the main crop harvested.
- An estimated 11.6 million ha of total fallows in India and 15% (1.76 million ha) area comes under West Bengal state only, can be targeted for producing pulses like lentil, grasspea and chickpea during *Rabi* (Nov-Feb) and\or summer(Mar-May) seasons.
- Among the limiting factors, the lack of understanding of the fallow dynamics, soil moisture regimes and unavailability of location specific short duration varieties are the key.
- Spatial analysis: MCDM- Useful in any GIS analysis where several criteria are incorporated and AHP- ability to weigh criteria.
- This approach will boost production, provide income to farmers and ensure nutrition for rural families also making the soils healthier.

OBJECTIVES

- Estimation of potential fallow areas (Hotspot) for winter (Rabi) pulses.
- Develop multi-criteria decision making technique using fuzzy approach for lentil feasibility analysis

DATA USED

Fallow Dynamics: Start date of fallow, End date of fallow, Length of the fallow (Duration)

Climate Data: Temperature (Min and Max), Rainfall and Net radiation

Topographic Data: Elevation, Slope, Drainage density and Flooding

Soil Data: Texture, Depth, Moisture, pH, OC, CEC and Salinity

METHODOLOGY

1. Potential fallow mapping using existing crop fallow dynamics
2. Data determination and processing
3. Criteria standardization (Fuzzy)
4. Weight determination-pairwise comparison (AHP)
5. Multi-Criteria Decision Making (MCDM):
   a) Climate suitability, b) Soil suitability, c) Topography suitability, d) Overall suitability for lentil
6. Spatial matching with potential fallow area and final lentil suitability.

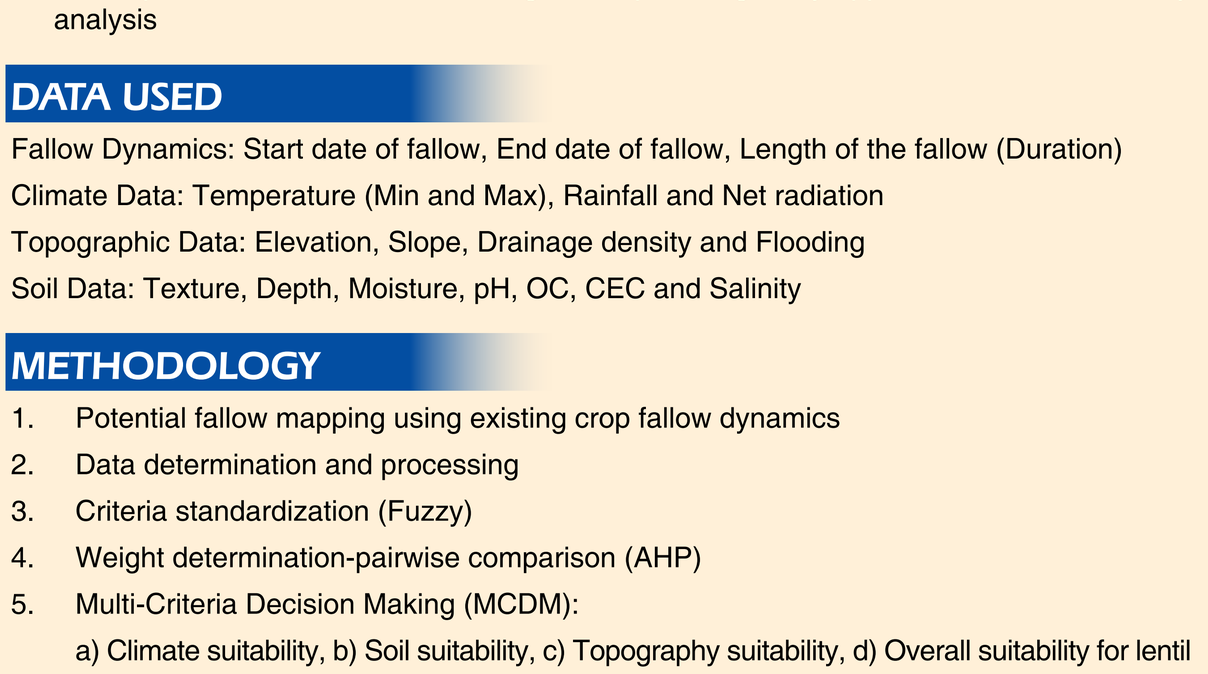
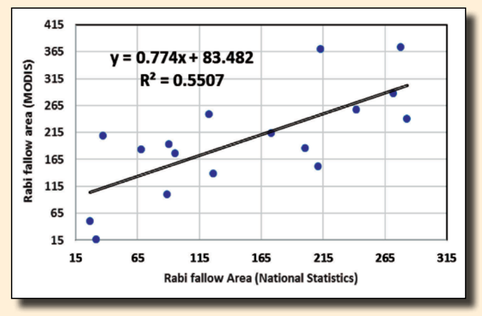


Fig. 1. *Methodology*

RESULTS AND DISCUSSION

The fuzzy-set model with analytic hierarchy process (AHP) in and MCDM in GIS domain to create final land suitability map for growing lentil in fallow areas. The suitability index $(SI) = \sum_{i=1}^{n} W_i * \mu_i(x)$ where n is the number of factors, *Wi* is the weight of factor i, which is computed by using AHP and μ_i is the membership grade for factor i. The value of SI is between 0 to 1. The distribution of overall suitability index pass through Kolmogorov-Smirnov test produced a p-value of < 0.001, which indicates that it is not strict normal distribution but it is slight right skewness.

The potential fallow areas (Hotspot) were estimated using fallow dynamics and reclassified using pulses crop calendar for the years 2001-2014. The final index were calculated using fuzzy gamma function. It is optimized using existing statistics of rice production and found more correlated at Gamma equals to 0.5. The results are in agreement with the actual production situation observed.



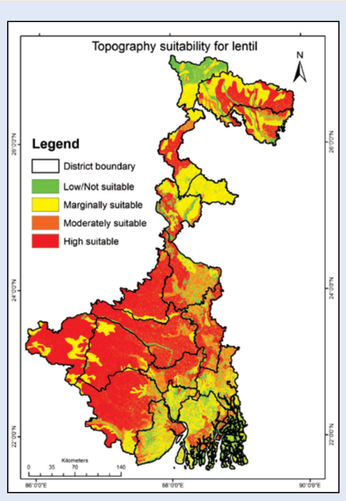


Fig. 2. *Topography suitability*

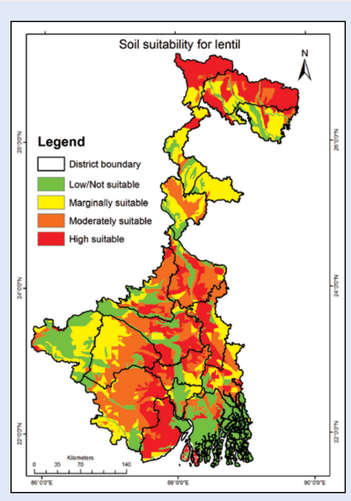


Fig. 3. *Soil suitability*

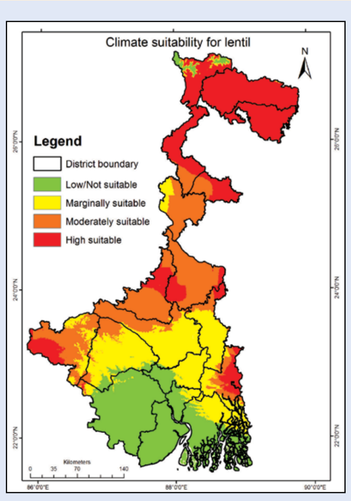


Fig. 4. *Climate suitability*

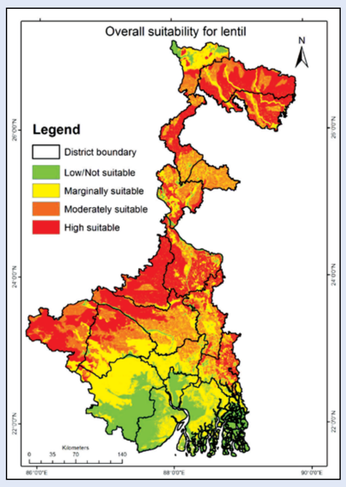


Fig. 5. *Overall suitability for lentil*

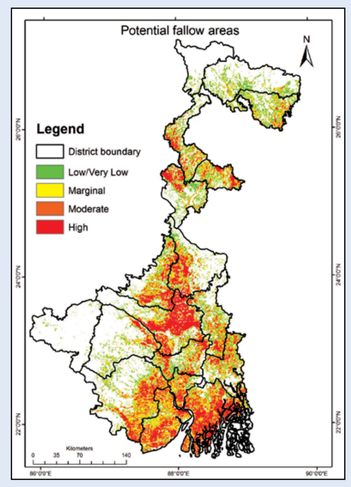


Fig. 6. *Potential fallow areas*

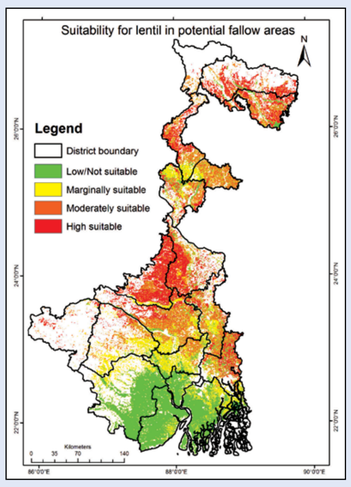


Fig. 7. *Lentil suitability in fallow areas*

The results showed that nearly 61% of the analyzed area are suitable for growing lentil in range of high suitable (21%) to moderately suitable (40%) followed by marginally (19%) to low/ not suitable (18%) for lentil production. The final results provide effective approaches to increase land use efficiency and better management for lentil production in fallow areas in West Bengal state of India.

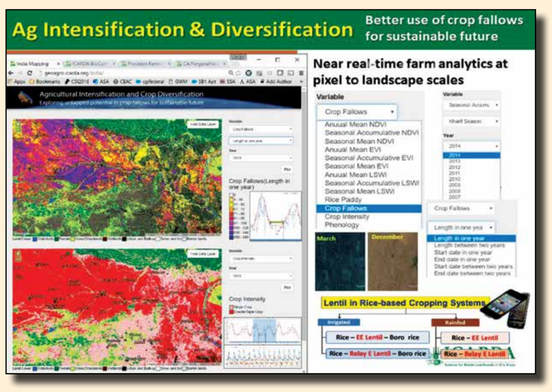


Fig. 8. *Ag Intensification (http://geoagro.icarda.org/intensification/)*

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