Invited Paper

Site Suitability Analysis of SRI (System of Rice Intensification) Cultivation in Potential Rice Cropped Areas of Andhra Pradesh: A Geospatial Approach

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Abstract

The study was undertaken to characterize the soils of Andhra Pradesh, India, for soil-suitability evaluation for SRI (System of Rice Intensification) cultivation in potential rice cropped areas using remote sensing and geographic information system based multi criteria evaluation. The soil attributes selected for suitability analysis for SRI rice are soil drainage, soil depth, soil texture and soil salinity. The study clearly brought out the spatial distribution of rice crop derived from remote sensing in conjunction with evaluation of soil suitability for SRI method of rice cultivation. The study indicates that about 21.67 lakh ha. of potential rice area is highly suitable for SRI followed by 11.41 lakh ha. of moderately suitable area. A marginal area of 37,102.96 thousand ha. was identified as slightly suitable for SRI method of rice cultivation in Andhra Pradesh.

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Key words: Site suitability, SRI, geospatial approach, remote sensing, GIS.

The System of Rice Intensification (SRI) is a method of rice cultivation that involves efficient utilization of natural resources along with judicious use of external inputs to produce optimum rice yields. SRI is a method of agronomic management of rice cultivation for increasing the yield of rice per unit area per unit time with reduced seed and water requirement and modified soil (field) ecosystem with special and mechanical arrangements. This improved method of rice cultivation was developed in 1983 in Madagascar by Fr. Henri de Lau Lanie in association with a non government organization – Association Tefy Saina (ATS) and with many small farmers which has later spread to many countries. SRI cultivation is a system rather than a technology and is based on the insights that rice has the potential to produce more tillers and grains than conventional method and

that early transplanting and optimal growth conditions, spacing, humidity, biologically active and healthy soil and aerobic soil conditions during vegetative growth can fulfill this potential. Major SRI principles include: (1) raising seedlings in well managed nurseries (2) careful transplanting of single and young (8–15 days old) seedlings at wide plant spacing (starting at 25 x 25 cm, but going up to 50 x 50 cm) (3) intermittent application of irrigation to avoid permanent flooding during the vegetative growth phase (4) addition of nutrients to the soil, preferably organic manures and amendments instead of chemical fertilizer (5) intensive manual or mechanical weed control without the use of herbicides. Sridevi and Chellamuthu (2012) reported that when all these principles are followed, it profoundly enhanced the growth and nutrient uptake which in turn improved the yield attributes and yield. The enhancement in the performance of rice was linearly proportional to the number of SRI components being practiced. As the SRI components increase, the performance of rice enhances. SRI that evolved in the 1980s in Madagascar is also gaining popularity in India. SRI saves not only the seed (a seed rate of 5–7 kg/ha as against 25–30 kg/ha for normal) but also saves water (35–40%) as the fields are not inundated continuously (Ghritlahre *et al.*, 2012; Nay-Htoon *et al.*, 2013;Thakur *et al.*, 2010). Rice is the major crop under canal, tank, and tube well irrigation systems in AP, with groundwater-based systems now constituting 50% of the gross irrigated area in the state. The normal practices of rice cultivation include transplanting seedlings about 25 days old, with a seed rate of 60-75 kg ha^{-1}, and continuous inundation of water until the grain filling stage. The large-scale shift from canal and tank irrigation to reliance on wells has placed stressful demands on the state's groundwater resources, with extraction exceeding recharge rates in several parts of Andhra Pradesh. The System of SRI was diffused first to Tamil Nadu State in India during the year 1999 (Johnson and Vijayaragavan, 2011; followed by Andhra Pradesh with systematic evaluation in on-farm comparison trials across all districts of the state. Although SRI has not spread across the state on a large scale, experiences in a number of areas can be assessed for its potential adaptation. Andhra Pradesh (AP) is among the several states considered as 'SRI-adopting' and hence, its diffusion process is of scientific interest. Ravindra and Laxmi, (2011) evaluated the Potential of the system of rice intensification for systemic

improvement in rice production and water use in Andhra Pradesh. Scientists from the Directorate of Rice Research, Hyderabad conducted field experiments from 2008 to 2010 and concluded that SRI practices creates favourable conditions for soil microbes to prosper, save irrigation water and increase grain yield (Gopalakrishnan *et al.,* 2013). SRI can become a viable alternative approach to the conventional transplanting having advantage of both in terms of higher yield and water productivity especially, in the areas of limited water situations (Kumar *et al.,* 2011).

Suitability is a function of crop requirements and land characteristics (Mustafa *et al.,* 2011). In order to explore the potential areas suitable for SRI, knowledge of soils, their properties, and spatial distribution is indispensable as it opens opportunities for a more rational management of the soil resources. Development of a GIS-based thematic database on soils is vital in crop-suitability analysis for optimal utilization of available resources (Coleman and Galbraith, 2000). Weighted overlay analysis is a component of spatial modeling using spatial multi-criteria evaluation. Weighted overlay analysis assigns more importance to some criteria over others (Hailegebriel, 2007; Zelalem, 2007). Multi-Criteria Evaluation (MCE) approaches and GIS is useful because various production variables can be evaluated and each weighted according to their relative importance on the optimal growth conditions for crops (Perveen *et al.,* 2007). In the present study, multi-criterial overlay analysis was carried out for soil site suitability for SRI method of rice cultivation in the potential rice growing area of Andhra Pradesh using GIS and remote sensing techniques.

Study area

Andhra Pradesh is selected for this study in order to evaluate the soil suitability classes for potential adaptation of SRI in the existing rice area. The state has 13.83 million ha of gross cropped area out of which 4.82 million ha is the net irrigated area with an irrigation intensity of 1.39 (2008-2009). In Andhra Pradesh, rice is grown in 22 districts, out of which 14 districts are falling under high productivity group, that is, yield more than 2500 kg/ha. More than 85 per cent of rice in the State is grown under different sources of irrigation under puddle condition whereas out of the rest, 10 per cent rice area lies in the rain-fed low land ecosystem and 5 per cent in the rainfed system.

Materials and Methods

For carrying out the soil suitability analysis, a geo-referenced digital soil map with attributes like drainage, texture, depth and salinity, etc., is required that could be used as a reference map. For this study, NBSSLUP soil map of 1:250,000 scale is used. The digital soil map of AP consists of 1249 polygons linked with an attribute table. Lambert Conformal Conic projection and Geographical coordinate system with WGS 84 datum was used in ARC GIS to generate all the thematic layers. The attributes selected for suitability analysis for SRI rice are: (1) Soil drainage (2) Soil depth (3) Soil texture (4) Soil salinity. The suitablity criteria of these properties are evaluated independently prior to jointly ranking them followed by multi criteria overlay analysis in GIS. The detailed methodology is presented in Fig. 1.

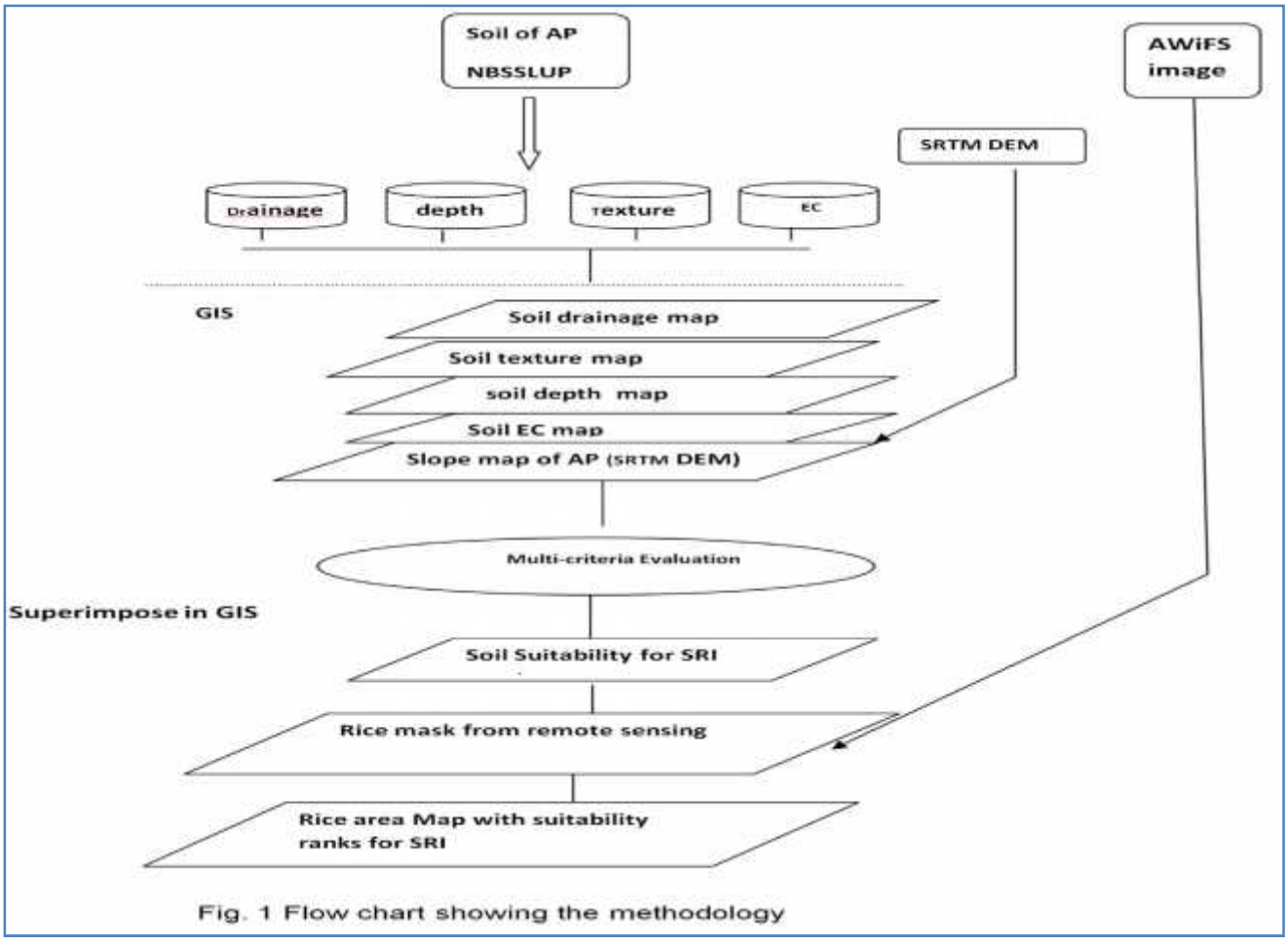

Fig. 1 Flow chart showing the methodology

Satellite DataAWiFS (Advanced Wide Field Sensor)

Potential rice area mask was generated using IRS-P6 (AWiFS) images. IRS-P6 (AWiFS) has a spatial resolution of 56 m, four spectral channels (green (0.52–0.59µm), red (0.62–0.68µm), near infrared (NIR: 0.77–0.86µm) and short-wave IR (SWIR: 1.55–1.70µm)) and a temporal resolution of 5 days with a 740 km swath width. Time series AWiFS images pertaining to the study area were processed in ERDAS IMAGINE software. AWIFS images were geo-referenced with Survey of India (SOI) topographic map (1:250,000). With ground truthing, supervised classification was carried out using maximum likelihood algorithm. The accuracy of the classification was evaluated using classification error matrix. Potential rice area mask was generated and overlaid on the soil suitability map to derive the rice area suitability for adaptation of SRI method in Andhra Pradesh.

DEM (Digital Elevation Model)

Shuttle Radar Topography Mission (SRTM) derived DEM of 90 m resolution was used to generate the slope map of AP. The data were taken from http://srtm.usgs.gov/data/obtaining.html. The study area was clipped, projected and then imported to the ArcGIS. Based on the data the slope map was generated.

Results and Discussion

Generation of thematic database in GIS

The rice growing soils in AP are varying in properties such as texture, drainage, pH, water holding capacity and nutritional status, etc. These soils are in various topographical, pedological and hydrological conditions in various land-forms. The most useful application of GIS in resource data analysis is to overlay various thematic maps to derive useful results. The factors which could influence soil-suitability evaluation for SRI have been defined and thematic layers on soil drainage, depth, texture, salinity and slope were generated. The present study has utilized the analytical capabilities of GIS in the evaluation of soil suitability for SRI method of rice cultivation in Andhra Pradesh.

Assigning weight and Multi Criteria Evaluation (MCE)

The purpose of weighting is to express the importance or preference of each factor relative to the other factor on SRI method of rice cultivation. Factors established in this phase are not unique but they are most relevant and expert opinion is very

important in this phase. Suitability levels for each of the above mentioned factors were defined and ranks were attributed accordingly. Once the composite layers and their weights were obtained, the multi criteria evaluation was carried out in GIS environment to produce the soil suitability maps for SRI method of rice cultivation in Andhra Pradesh.

Soil drainage

The wetting and drying cycles are regarded as critical to yield performance, with the intermittent drying promoting root development in a way that is not possible under a 'wet' regime. Hence, soil drainage is the most important physical attribute of soil for SRI method. Soil drainage classes derived from NBSSLUP soil map of 250,000 scale is shown in Fig. 2. Though there are five drainage classes altogether, for this study the soils of AP were categorized into three drainage classes according to the suitability for SRI method of rice cultivation.

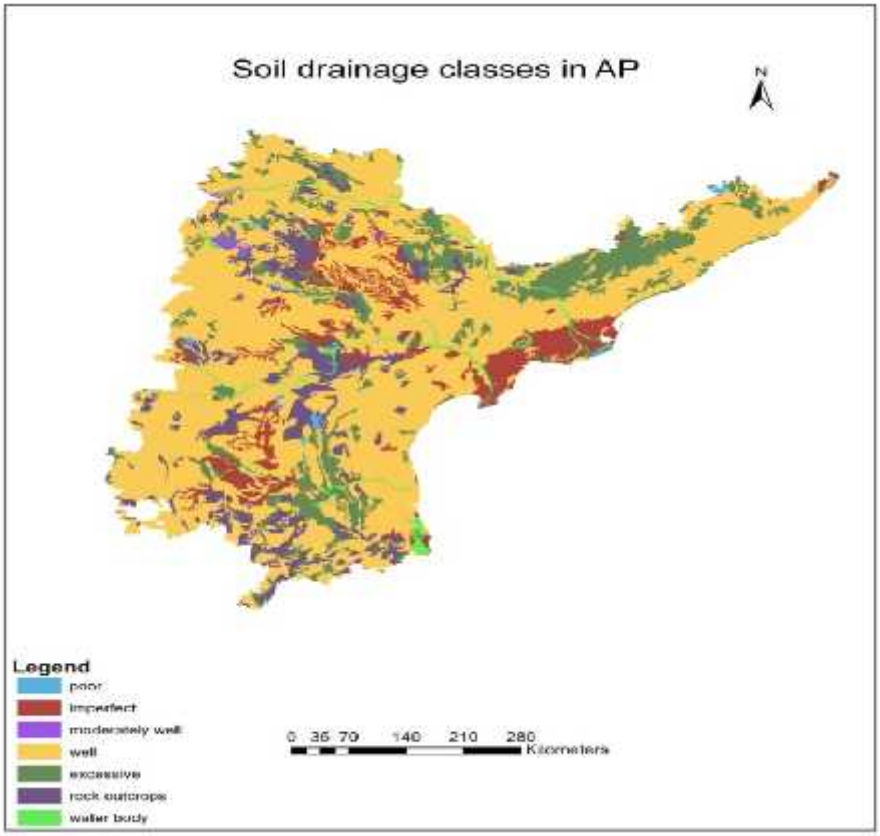

Fig. 2: Soil drainage classes in AP

The poorly drained soils are sparsely distributed particularly in the north eastern and central part of AP. The well drained soils are given lowest weight of 1 (most suitable), the moderately well drained as well as the imperfectly drained soils are given a weight of 2 and lastly, poor and excessive drainage classes are attributed the highest weight of 3 (least suitable). When the drainage map is overlaid on the potential rice map, it was found that approximately 24.24 lakh ha of rice area is well drained and best suitable for SRI, followed by moderately well drained class of approximately 6.82 lakh ha. and approximately 2.38 lakh ha. of poorly drained soil.

Soil depth

Soil depth is one of the most important soil physical parameters for SRI method of rice cultivation. Soil depth determines roots growth as well as presence of volume of water and air in the soil. In shallow soil, the crops suffer sub optimal conditions in the limited soil volume, which hinders growth and yield of the crop. The depth limitations also vary with the kind of clay mineral present. According to the soil map of 250,000 scale, the soils of AP are categorized into four classes as shown in the Fig. 3. Maximum area of AP is covered by deep soil. For studying the soil suitability for SRI method of rice cultivation, the soils of AP were categorized into two depth classes, and it is observed that most of the rice area in AP are deep or moderately deep. The shallow and very deep soils are sparsely distributed throughout AP. As intermittent irrigation is practiced in SRI during vegetative growth to keep the soil just saturated or moist enough to avoid drought stress, the deep/moderately deep soils are given lowest weight of 1 (more suitable) and shallow as well as very deep classes are attributed the weight of 2 (less suitable). It was observed that most part of potential rice cropped area of approximately 30.836 lakh ha. is more suitable to SRI method and approximately 2.529 lakh ha. is less suitable when soil depth is considered alone.

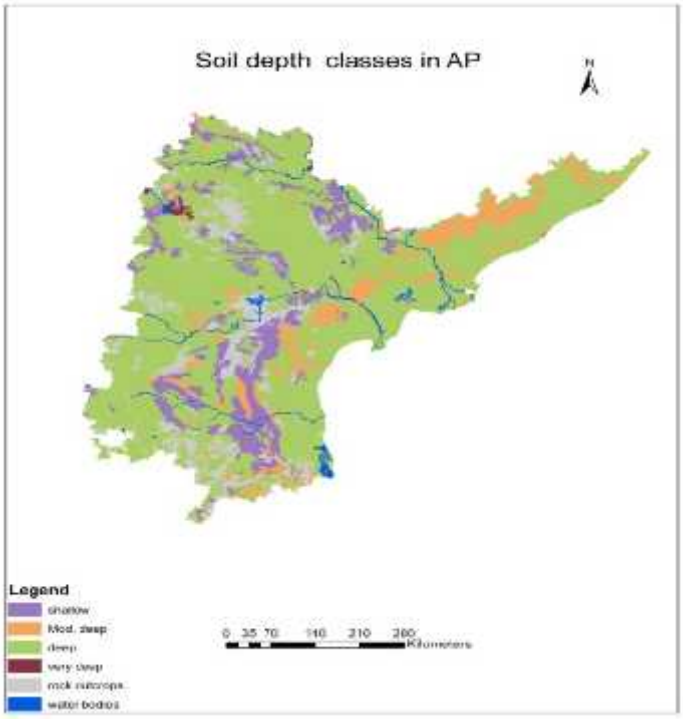

Fig. 3: Soil depth classes in AP

Soil texture

Soil texture has a large influence on irrigation water requirement due to much higher percolation losses on coarser textured soils. Hence, soil texture is an important parameter for rice system. According to the soil map of 250,000 scale, the soils of AP are categorized into five textural classes as shown in the Fig. 4. Clayey soil covers the maximum area. As physical condition of soil is very important criteria for SRI and well drained soil is preferred, the soils of AP categorized into three texture classes for this study. It was observed that approximately 7.925 lakh ha. of rice area is covered with best suitable soil texture (loamy and clay skeletal) for SRI and the maximum rice area of approximately 23.343 lakh ha. is moderately suitable for SRI as far as soil texture is concerned. Approximately 2.231 lakh ha. rice area is with poor soil texture which might cause poor or excessive drainage.

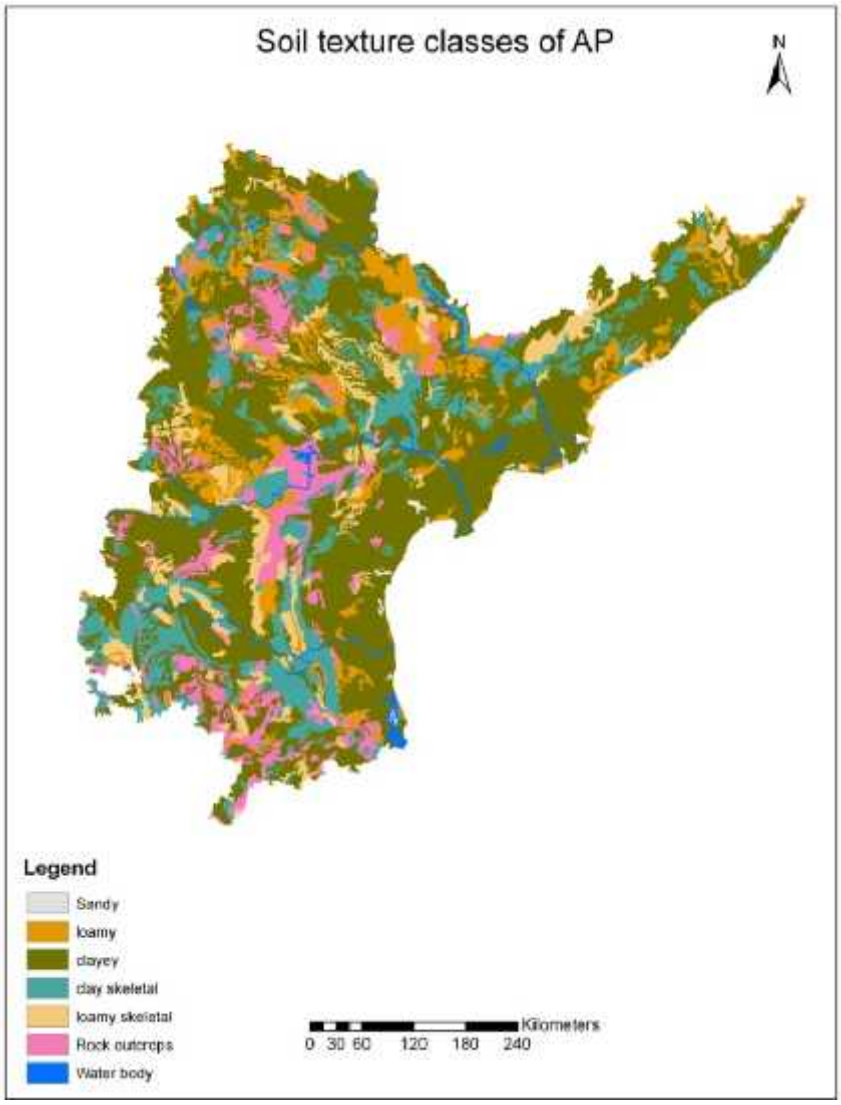

Fig. 4: Soil texture classes in AP

Loamy and clayey skeletal texture classes are attributed a weight of 1 as they are well suited for SRI, clayey texture is given a weight of 2 which is moderately suitable and sandy, loamy skeletal texture classes are attributed a weight of 3 which are least suitable due to excessive drainage and low water retention properties.

Soil salinity

As shown in Fig. 5, there are 6 salinity classes in the NBSSLUP soil map of 250,000 scale and normal soil occupies most of the area in AP. As high saline soils are not suitable for SRI system, the soils of AP categorized into two salinity classes for this study. It is observed that entire rice area of

approximately 33.091 lakh ha. is non saline where as 21,487 thousand ha. rice area is having moderate to strong salinity problem.

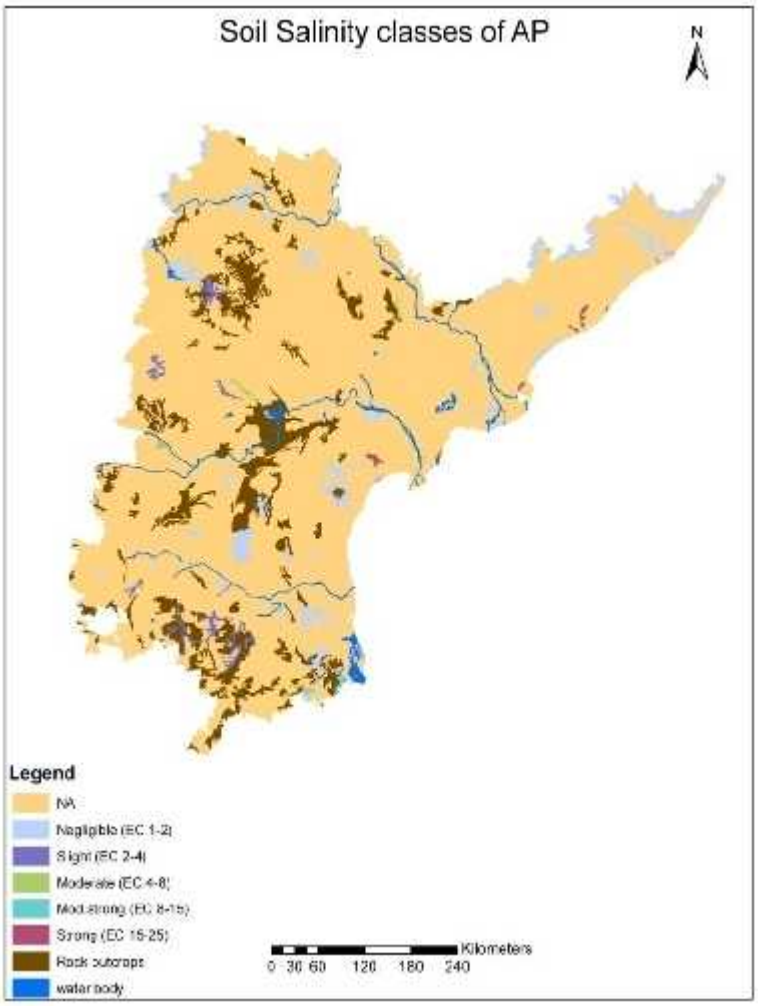

Fig. 5: Soil salinity classes in AP

Slope

Slope map was generated from the SRTM derived DEM of 90m resolution for the state of AP and presented in Fig. 6. It is observed that most of the potential rice grown area in the state is lying on the flat terrain with slope less than 15 degree. As far as potential rice grown area of AP and adaptation of SRI based on soil criteria are concerned, the slope effect is not significant.

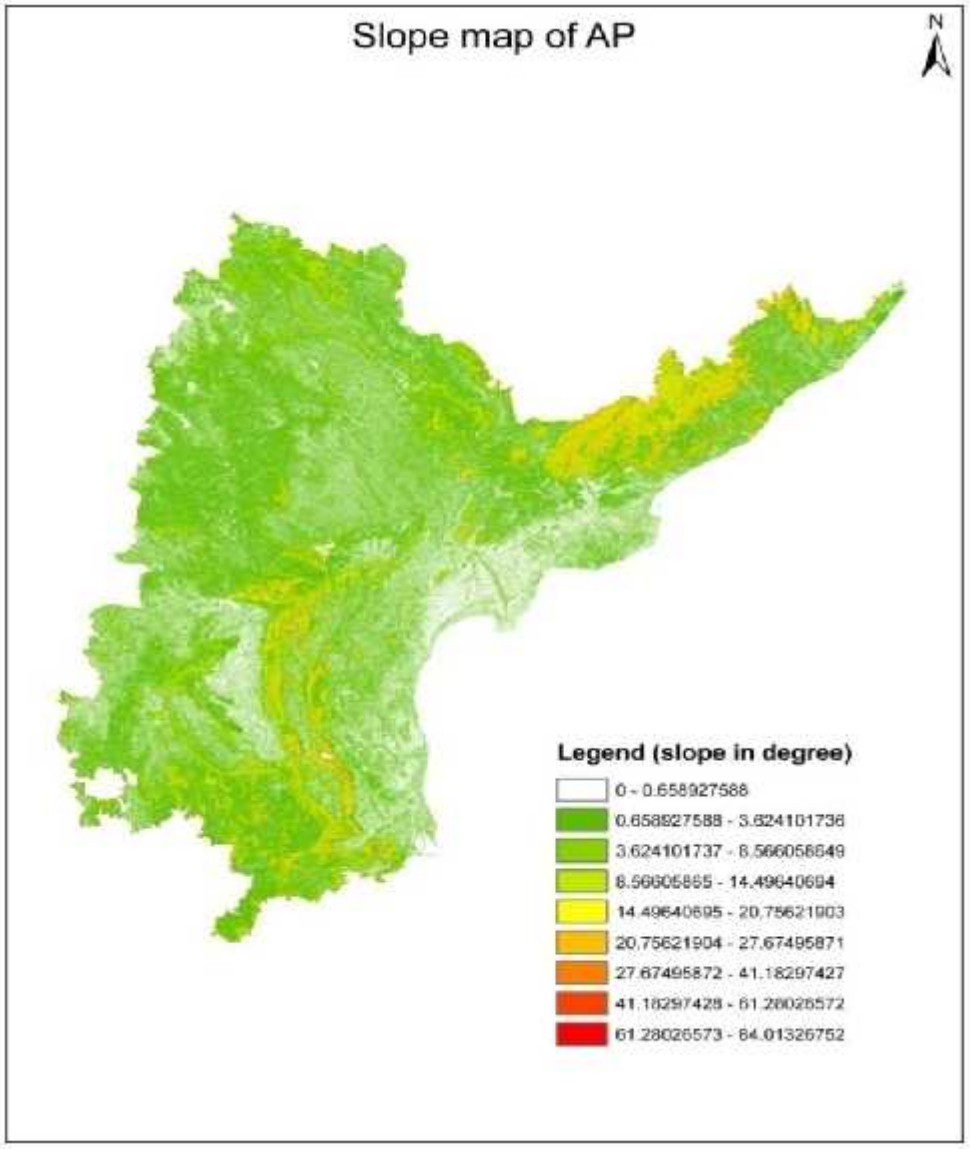

Fig. 6: Slope map of AP

Multi criteria Evaluation for soil suitability analysis for SRI system

After preparing thematic maps and giving weightage to the respective soil parameters according to the soil suitability for SRI method of rice cultivation, multi-criteria evaluation was carried out in GIS to arrive at suitability classes. Four soil criteria along with their associated categories (3x3x2x2) are considered resulting in 36 possible combinations with total weightage ranging from 4 to 9. As more suitable classes are attributed lower weightage, the final weightage of 4-5 are grouped into the highly suitable class (S1) followed by moderately suitable class (S2) with weightage 6-7; and

slightly suitable (S3) with weight 8-9 (Table 1). It is to be noted that, as our analysis is confined to the potential rice grown area in the state, only the rice area with different suitability classes for SRI is shown in the map (Fig.8). The potential rice cropped area derived from AWiFS images (Fig.7) was overlaid on the soil suitability map and the extent of each suitability class was calculated. It is observed that most of the rice area is best suitable for SRI followed by moderately suitable class. A very small fraction of rice area is found slightly suitable for SRI method of rice cultivation. Negligible area was classified as non suitable class.

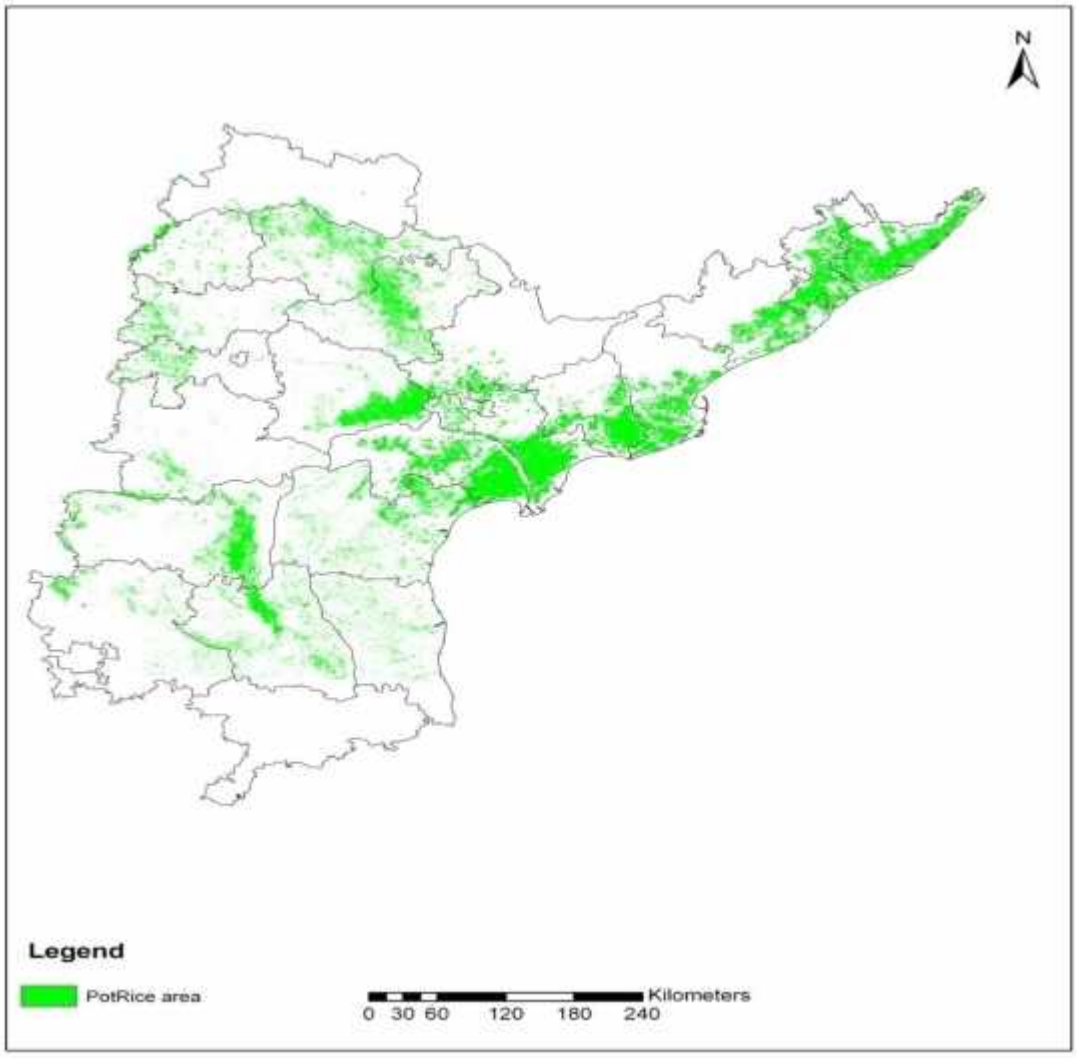

Fig. 7: Potential Rice area derived from AWiFS

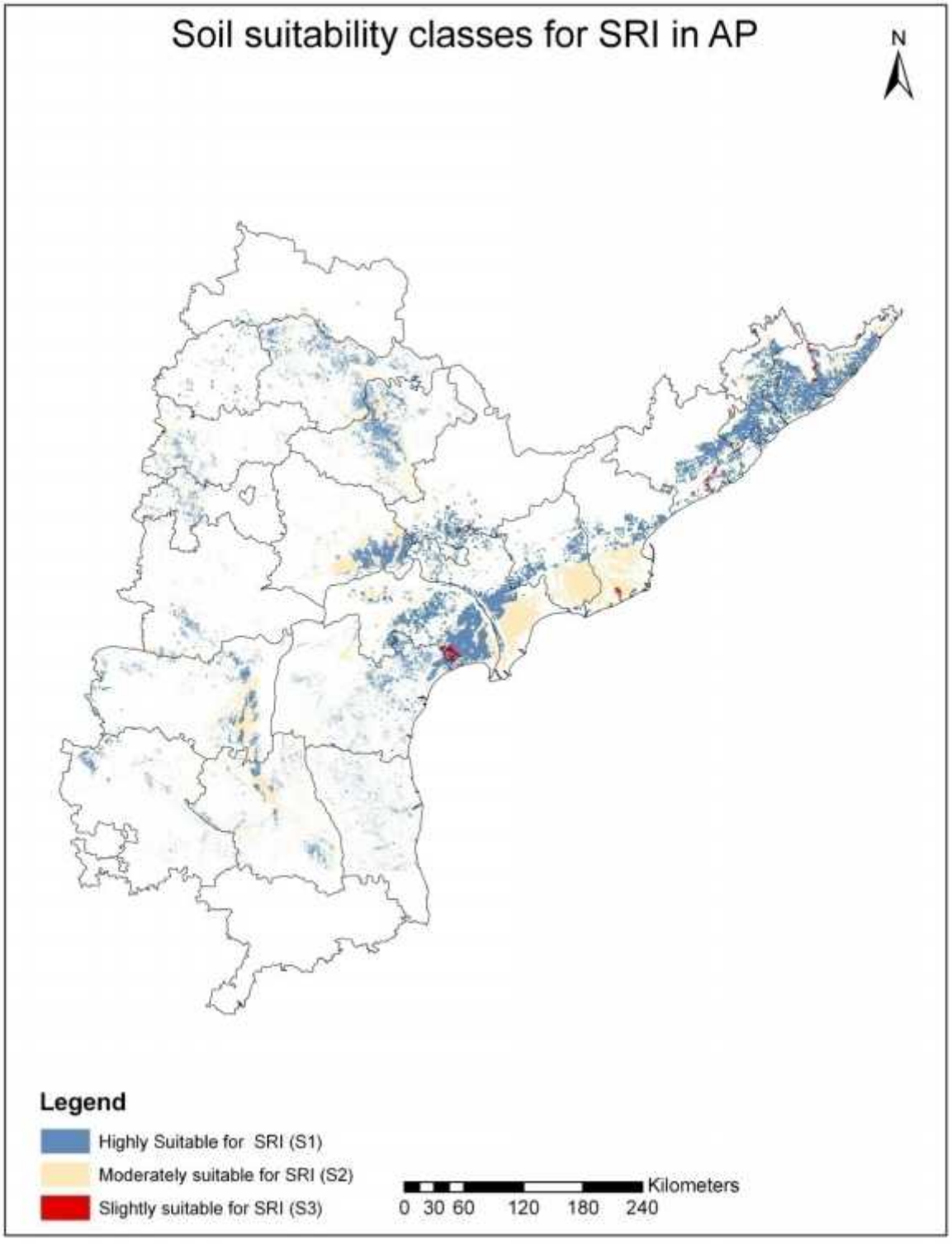

Fig. 8: Soil suitability classes for SRI in AP

Conclusions

In this study, Remote Sensing (RS) and GIS techniques were applied to identify suitable areas for SRI cultivation of rice in Andhra Pradesh, based on soil criteria. The results obtained from this study confirm that RS, GIS and multi-criteria evaluation techniques proved to be effective tools for soil-site suitability analysis studies. The study clearly brought out the spatial distribution of rice crop derived from remote sensing in conjunction with evaluation of soil suitability for SRI method of rice cultivation. However, further studies are suggested, for including more number of soil parameters and other socio-economic data like irrigation facility etc., that affect the adaptation of SRI method of rice cultivation in the state.

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Table 1: Potenital area suitable for SRI based on multi- criteria evaluation

Rank scored in multi-criteria weight overlay analysis	Suitability for SRI system	Potential Rice Area of AP
4-5	S1;Highly Suitable	21.675 lakh ha.
6-7	S2; Moderately Suitable	11.410 lakh ha.
8-9	S3; Slightly Suitable	37,102.96 thousand ha.