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Spatial Variability of Bt Cotton On-farm Situation: A Survey

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The survey was carried out during November 2015 in selected cotton fields of seven villages *viz.,* Kalmala, Jagir Venkatapur and Ijapur of Raichur district and Gogi, Ulalkal, Hothpet and Maddarki villages of Yadgir districts covering part of TBP and UKP irrigation commands, respectively. The villages were selected based on the predominance of cotton area. Farmers plots were visited and location were recorded using GPS and observations were made on management practices, leaf reddening incidence and per cent leaf reddening, NDVI values, chlorophyll content, anthocyanin content and seed cotton yield. The spatial variability maps were generated using "krigging", and interpolation method under GIS environment using observations on spatial spectral variability in NDVI, SPAD (chlorophyll content), anthocyanin content, leaf reddening index, reddening

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percentage and seed cotton as influenced by irrigation ecosystem, soil type and foliar spray of 19:19:19, date of sowing and cultivars. The data was further subjected for correlation studies. There is a lot of variation in the seed cotton yields among *Bt* cotton farmers across the Upper Krishna project and Tunga Bhadra Project irrigation commands of the state. Soils cultivated and cultivars used often remain the same the difference in yield could be due to nutritional management, the occurrence of leaf reddening, other factors, or combination of many of these attributing characteristics. Since leaf health is indicative of plant health and yield in turn, leaf health could be assessed through leaf spectral reflectance viz, NDVI, SPAD, and LRI. Based on this a survey was undertaken in November 2015 at Raichur (in three taluks) and Yadgir (in four taluks) districts falling under TBP and UKP irrigation commands, respectively, taking in all 90 farmers. The spectral observations were made on standing field crops besides leaf samples were collected to estimate leaf anthocyanin in the laboratory and GIS mapping was done using ESRI-made ArcGIS version 10.4 from Sujala-III, Remote Sensing and GIS laboratory, College of Agriculture, Raichur, was used to import GPS data and field data attachment for spatial analysis of leaf reddening incidence in cotton. The results on Spectral observations on NDVI, SPAD, leaf reddening index, reddening percentage in addition to leaf anthocyanin content varied due to locations, irrigation or otherwise, foliar spray, fertilization level, date of sowing, and cultivars.The leaf chlorophyll content is an important biometric character, the content quality, and duration (stability) indicate general crop health and ultimately yield directly if not influenced by the rate and efficiency of translocation to sink (*kapas* yield in case of cotton), therefore, it is often used to monitor real-timeN fertilization (LCC, SPAD, Green Seeker) as well as to forecast crop condition and yield. Periodic spectral observations on SPAD and NDVI are useful indicators of crop health and performance in commercial crop like cotton which could be extrapolated to field scale for crop management and production forecast.

Keywords: Bt cotton; SSNM; RDF.

1. INTRODUCTION

Cotton (*Gossypium* spp.), 'the king of fibers' also popularly known as 'the white gold' enjoys a pre-eminent position among cash crops in the world and India as well. In India, the crop is cultivated in 10.50 m ha with a production of 35.10 million bales of seed cotton (2016-2017), and the country is very close in production to China ranking first in the world. The average productivity of cotton in India, however, is low (568 kg lint ha-1) when compared to the world average (725 kg lint ha^{-1}) (CAB, 2016) or the leading producers namely, Australia (1781 kg ha^{-1}), China (1719 kg ha^{-1}), Brazil (1522 kg ha^{-1}), the USA (974 kg ha^{-1}) and Pakistan (699 kg ha^{-1}).(CAB, 2016).

Leaf health in general and nitrogen deficiency in particular can slow cotton growth and ultimately limit yield while an excess of available N can delay maturity, increase incidence of boll rot, and lower efficacy of defoliation. Since N is a component of chlorophyll, leaves deficient in N have less chlorophyll and may appear yellowish green or red (red leaf malady complex). Leaf reflectance properties in visible region of the spectrum (400 to 700 nm) depend primarily on chlorophyll concentration and could reveal leaf health/plant health and thereby ultimately its performance. Therefore, of late vegetation spectral indices are evolving as potent non-destructive indicators of crop health and productivity and hence efforts are on to refine and develop recommendations to use this technology as a tool in precision agriculture particularly in crops of commercial importance.

Further, majority of the cotton growing farmers not following the SSNM in Command areas of Karnataka which advocates need based supply of nutrients and ensures application of nutrients at right time in desired quantities by the crop for obtaining set yield targets. Initial studies carried in this regard in UKP and TBP irrigation commands were promising at lower targets (4 t ha^{-1}), however higher yield targets (≥ 5 t ha^{-1}) in spite being possible were elusive warranting further refinement of agronomic practices [1-3]. So far, today, the farmers should aim at harvesting some pre set yield goals by adopting best management practices rather getting what comes following down the mill practices. This, however, needs sound technical backup on achievable targets in a specific agro-ecology, best time of planting and adequate and holistic nutrition, and knowledge on spatial and temporal variability in varietal responses to climate and soil. In this context, the present investigation in *Bt* cotton (*Gossypium hirsutum* L.) under TBP irrigation command was planned with the objective to assess spatial variability, spectral reflectance and crop productivity in Bt cotton on farmers fields.

2. MATERIALS AND METHODS

Since leaf health is indicative of plant health and yield in turn, leaf health could be assessed through leaf spectral reflectance viz, NDVI, SPAD, and LRI. Based on this a survey was undertaken in November 2015 at Raichur (in three taluks) and Yadgir (in four taluks) districts falling under TBP and UKP irrigation commands, respectively, taking in all 90 farmers. The spectral observations were made on standing field crops besides leaf samples were collected to estimate leaf anthocyanin in the laboratory. A questionnaire was prepared for collecting details of farmers and the production practices of surveyed farmers are presented. The means values are presented along with correlations between spectral observation and yield. The data on the various observations were taken in the farmer's field and all the data were subjected to correlation studies. Correlation coefficients were worked out between the seed cotton yield independent variables affecting the yield like SPAD chlorophyll content (SPAD reading), total chlorophyll content, anthocyanin content, NDVI values, canopy temperature, red leaf index (RLI). Geographical Information System (GIS): ESRI made ArcGIS version 10.4 from Sujala-III, Remote Sensing and GIS laboratory, College of Agriculture, Raichur, was used to import GPS data and field data attachment for spatial analysis of leaf reddening incidence in cotton. Global Positioning System (GPS): Trimble-made Juno SB handheld GPS was used to collect latitude and longitude of the sampling point. The Juno SB GPS is capable of receiving GNSS (Global Navigation Satellite System) signals. Care was taken to record the latitude and longitude when the PDOP (Positional Dilution of Precision) value was less than 3 to achieve better accuracy.

3. RESULTS AND DISCUSSION

The survey was carried out in November 2015 in selected cotton fields of seven villages *viz.,*Kalmala, Jagir Venkatapur, and Ijapur of Raichur district and Gogi, Ulalkal, Hothpet, and Maddarki villages of Yadgir districts covering part of TBP and UKP irrigation commands, respectively. The villages were selected based on the predominance of cotton areas. Farmers' plots were visited, and locations were recorded using GPS and observations were made on management practices, leaf reddening incidence and percent leaf reddening, NDVI values, chlorophyll content, anthocyanin content, and seed cotton yield. The spatial variability maps were generated using 'kriging", and interpolation method under GIS environment using observations on spatial spectral variability in NDVI, SPAD (chlorophyll content), anthocyanin content, leaf reddening index, reddening percentage and seed cotton as influenced by irrigation ecosystem, soil type and foliar spray of 19:19:19, date of sowing and cultivars. The data was further subjected to correlation studies. The results are presented here.

The survey data on spectral observations (NDVI, SPAD, LRI and reddening percentage) and leaf anthocyanin revealed variability between the irrigation commands across villages, among villages in the individual commands, between irrigated and rainfed culture and soil types (black soil and red soil), foliar spray (19:19:19), cultivars used (17 cultivars), rate of fertilizer nutrient (N, P and K) application and dates of planting (Tables 1 and 2). Between the irrigation commands, NDVI, SPAD and LRI values were relatively higher in the UKP irrigation command (0.64, 36.7 and 2.12, respectively) compared to TBP irrigation command (0.61, 34.5 and 2.07, respectively). Leaf anthocyanin was also lower (0.14 mg g^{-1} fresh weight) in UKP command compared to TBP irrigation command. This was also reflected in the leaf reddening index. Consequently upon which, average seed cotton yield was higher in UKP command compared to TBP (2980 kg ha^{-1} and 2683 kg ha^{-1}, respectively).

Among the villages, Kalmala fared better in TBP irrigation command and Hothpet fared better in UKP command. Further, across the irrigation commands, irrigated culture fared better with higher NDVI and SPAD values, lower anthocyanin content, LRI and reddening percentage and consequently higher yield (0.66, 37.7, 0.13 mg g^{-1} fresh weight, 2.00, 21.79 and 3056 kg ha^{-1}, respectively). Yield also revealed wide range in irrigated culture. Between the soils, black soils fared better with higher spectral indices, lower leaf anthocyanin contents and lower leaf reddening index and reddening percentage which resulted in higher seed cotton yield in black soil (0.63, 35.8, 0.15 mg g^{-1} fresh weight, 2.04, 22.39 and 2804 kg ha^{-1}, respectively) compared to red soil (0.55, 33.01, 0.14 mg g^{-1} fresh weight, 2.49, 25.65 and 2348 kg ha^{-1}, respectively). The foliar spray had an appreciable influence wherein spray of 19:19:19 soluble fertilizer at 1% resulted in higher NDVI and SPAD values, and lower leaf anthocyanin, leaf reddening index, and reddening percentage (0.66, 37.3, 0.14 mg g^{-1} fresh weight, 1.99 and 21.47,respectively) which resulted in higher kapas yield (3068 kg ha^{-1}) over no spray; control.

The leaf chlorophyll content is an important biometric character, the content quality, and duration (stability) indicate general crop health and ultimately yield directly if not influenced by the rate and efficiency of translocation to sink (*kapas* yield in case of cotton), therefore, it is often used to monitor real-timeN fertilization (LCC, SPAD, Green Seeker) as well as to forecast crop condition and yield. Being constituent of chlorophyll N content can be directly related to chlorophyll content of the leaf, so also balance among P, K, Mg, and Zn, etc. in the leaf. In the study, spatial spectral observation *viz.,* SPAD readings and NDVI were considered for the purpose. SPAD Chlorophyll is a simpler and non-destructive tool for relative contents of chlorophyll that is directly proportional to leaf nitrogen [4]. Similarly, NDVI is the measure of light reflectance in the visible reason spectrum (400-700 mm) depending primarily on chlorophyll concentration and hence it is also used as anon-destructive indicator of plant health and productivity [5]. Therefore, NDVI and SPAD were recorded. Correlation studies indicated positive and significant relations between them and both with yield.

Table 1. Spatial variation of spectral reflectance, leaf reddening, chlorophyll content, NDVI values, Anthocyanin content and cotton yield (kg ha^{-1})

Name of village		TBP irrigation command				
		LRI	**SPAD chlorophyll**	**NDVI**	**Anthocyanin content**	**Cotton yield**
Kalmala	TBP commands	1.35	41.9	0.79	0.13	3916
Jagir Venkatapur		2.21	30.3	0.54	0.16	2041
Ijapur		2.66	31.3	0.5	0.17	2093
AVERAGE		**2.07**	**34.51**	**0.61**	**0.15**	**2683**
		UKP irrigation command				
Gogi	UKP command	1.94	36.8	0.66	0.15	2780
Hothpet		2.04	37.4	0.68	0.13	3414
Ulkal		2.05	37.2	0.64	0.15	2866
Maddarki		2.43	35.2	0.57	0.13	2858
AVERAGE		**2.12**	**36.7**	**0.64**	**0.14**	**2980**

Table 2. Data on farmers field about average chlorophyll content, NDVI values, anthocyanin content, leaf reddening index, reddening percentage and seed cotton yield of cotton influenced by irrigation ecosystem, soil type and foliar spray of 19:19:19 during flowering to boll bursting stage

	Chlorophyll content	**NDVI**	**Anthocyanin content**	**Leaf reddening index**	**Reddening percentage (Visual)**	**Yield (kg/ha)**
Irrigated	37.7 (21.2-49.7)*	0.66 (0.24-0.94)*	0.13 (0.19-0.08)*	2.00 (0.7-3.6)*	21.79 (10-35)*	3056 (1200-4800)*
Rainfed	30.8 (24.3-40.8)*	0.52 (0.41-0.71)*	0.16 (0.12-0.19)*	2.41 (1.6-3.0)*	25.59 (20-30)*	2081 1200-3400*
Black	35.8 (21.2-49.7)*	0.63 (0.24-0.94)*	0.14 (0.08-0.19)*	2.04 (0.7-3.6)*	22.39 (10-35)*	2804 (1200-4800)*
Red	33.01 (28.2-48.3)*	0.55 (0.34-0.93)*	0.15 (0.08-0.19)*	2.49 (0.8-3.1)*	25.65 (10-30)*	2348 (1200-4700)*
19:19:19	37.23 26.45-49.7*	0.66 0.42-0.93*	0.14 0.08-0.19*	1.99 0.7-3.1*	21.47 10-30*	3068 1200-4800*
Without spray	31.2 21.2-47.0*	0.52 0.24-0.84*	0.15 0.11-0.18*	2.42 0.9-3.6*	26.13 10-35*	2170 1200-4200*

**range*

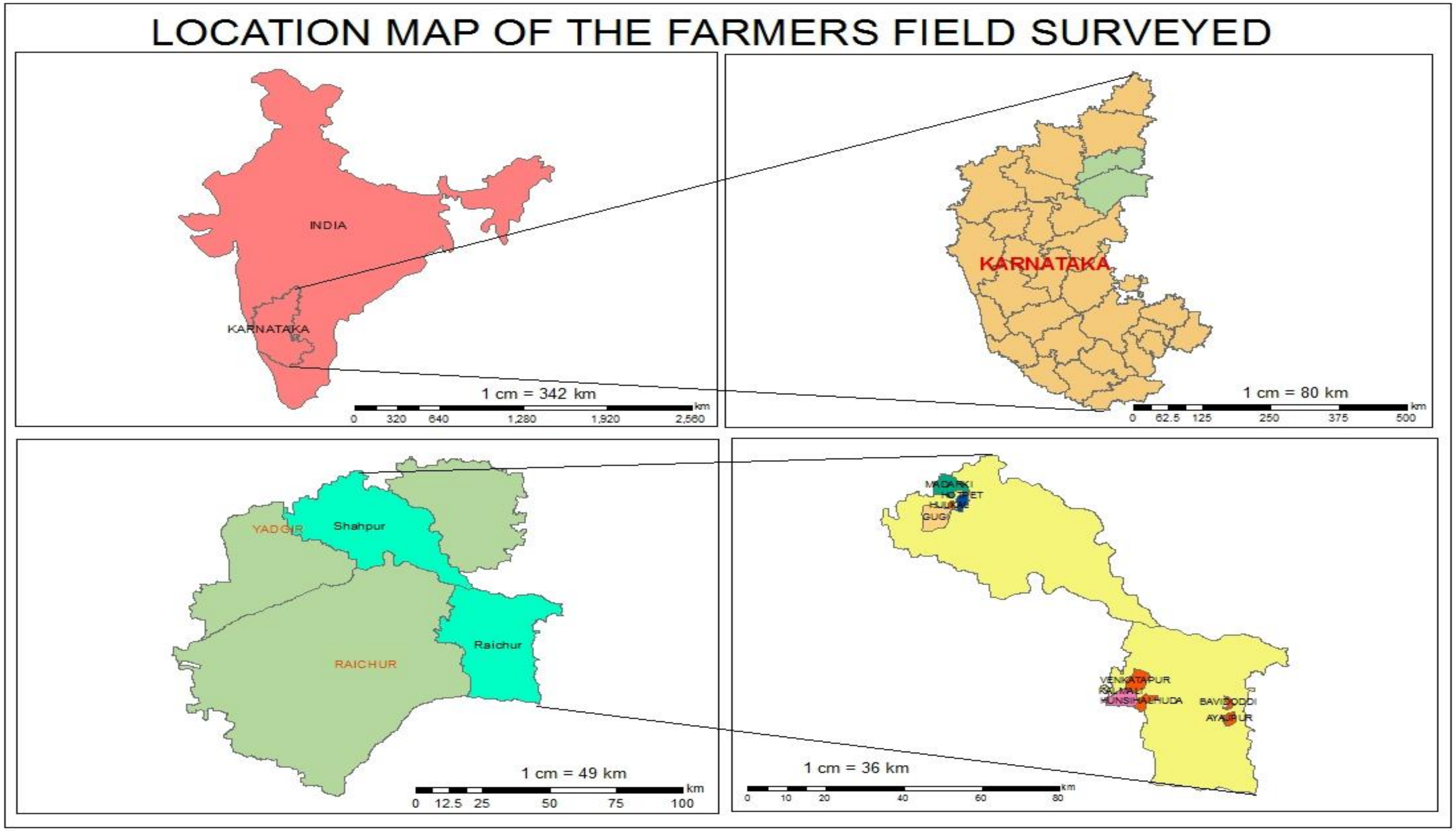

Fig. 1. Location map of the survey area

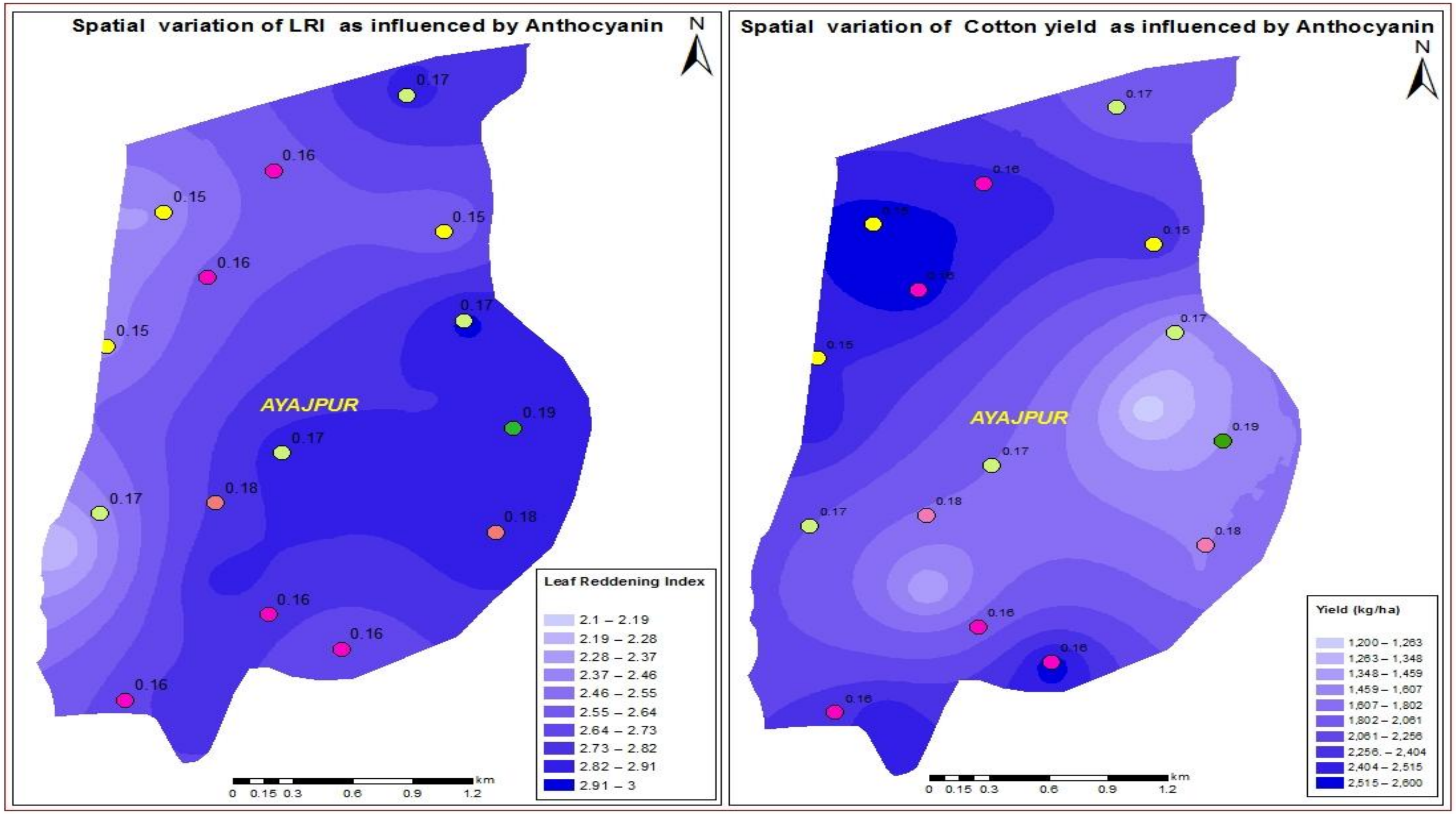

Fig. 2. Spatial variation of leaf reddening index and cotton yield with respect to anthocyanin content at Ayajpur village

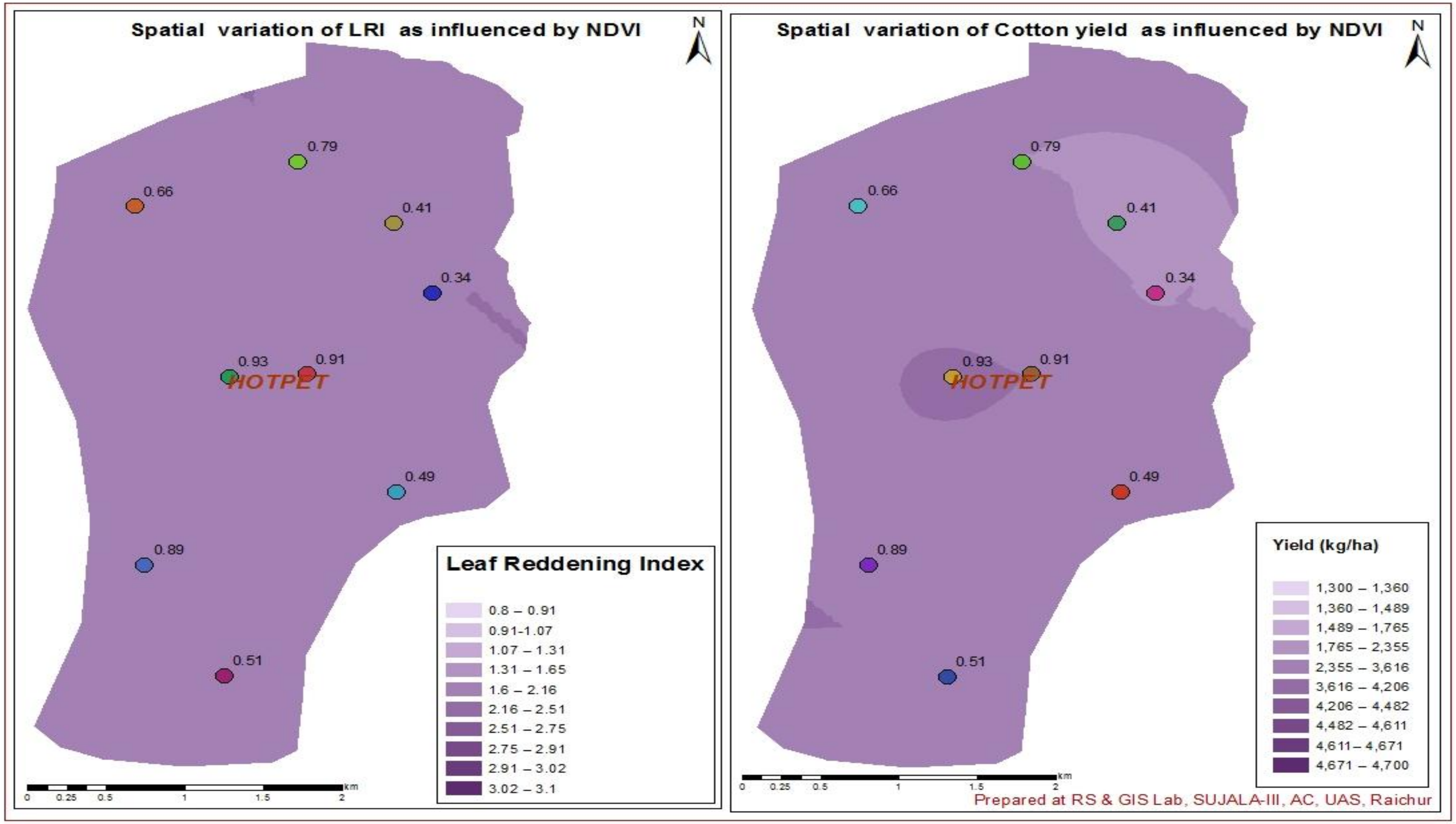

Fig. 3. Spatial variation of leaf reddening index and cotton yield with respect to NDVI values at Hothpet village

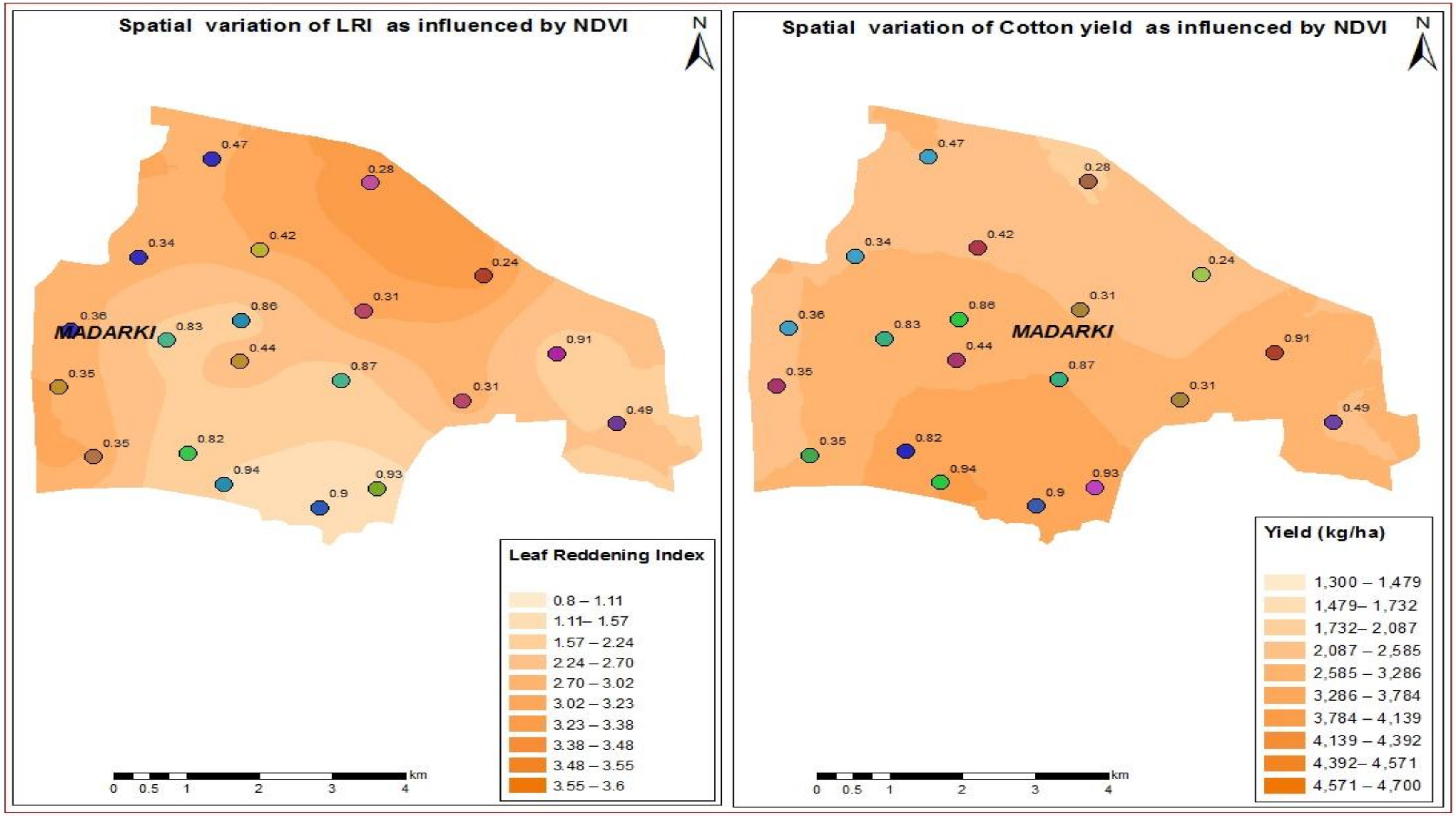

Fig. 4. Spatial variation of leaf reddening index and cotton yield with respect to NDVI values at Maddarki village

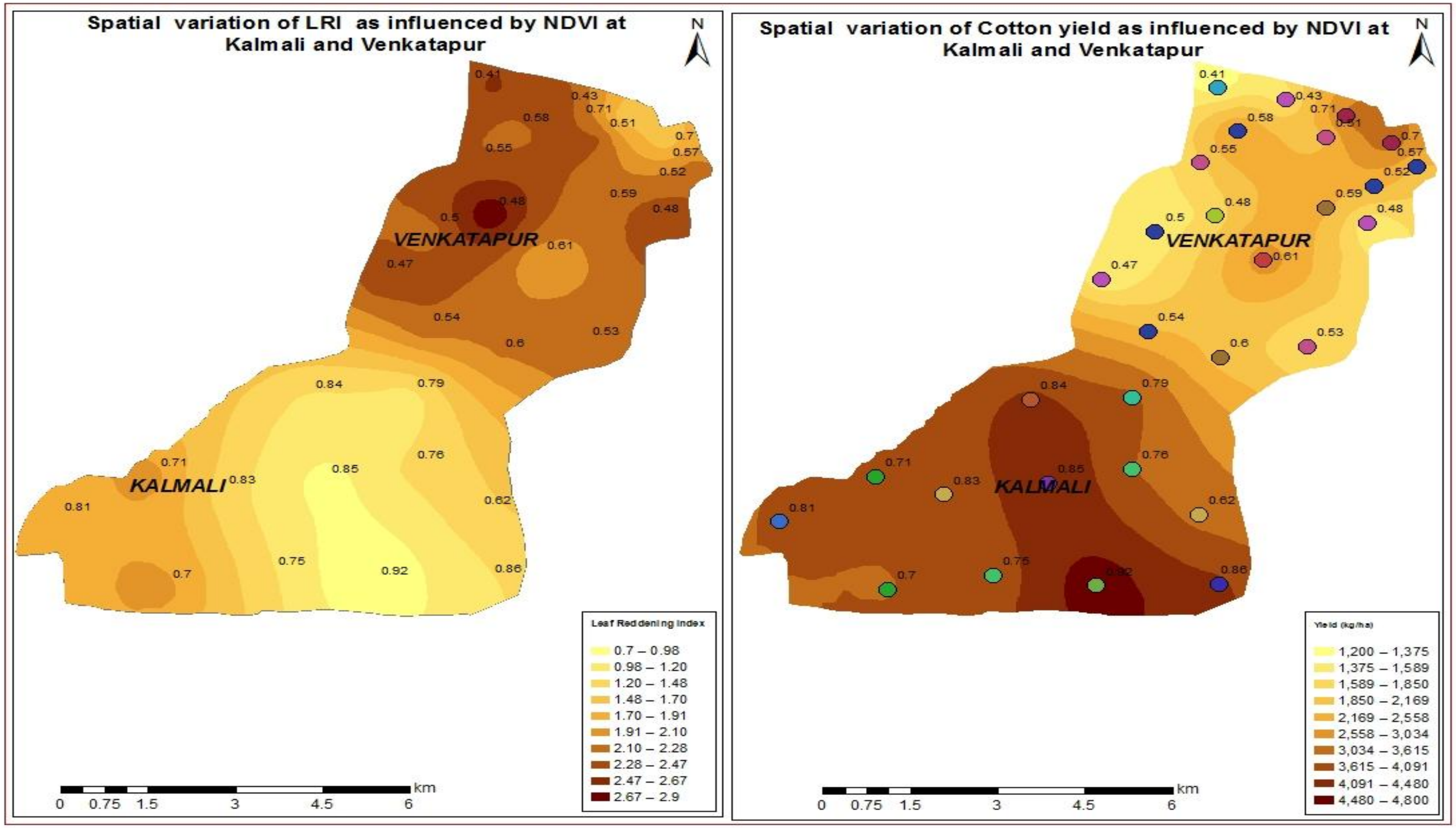

Fig. 5. Spatial variation of leaf reddening index and cotton yield with respect to NDVI values at Kalmala and Venkatapur village

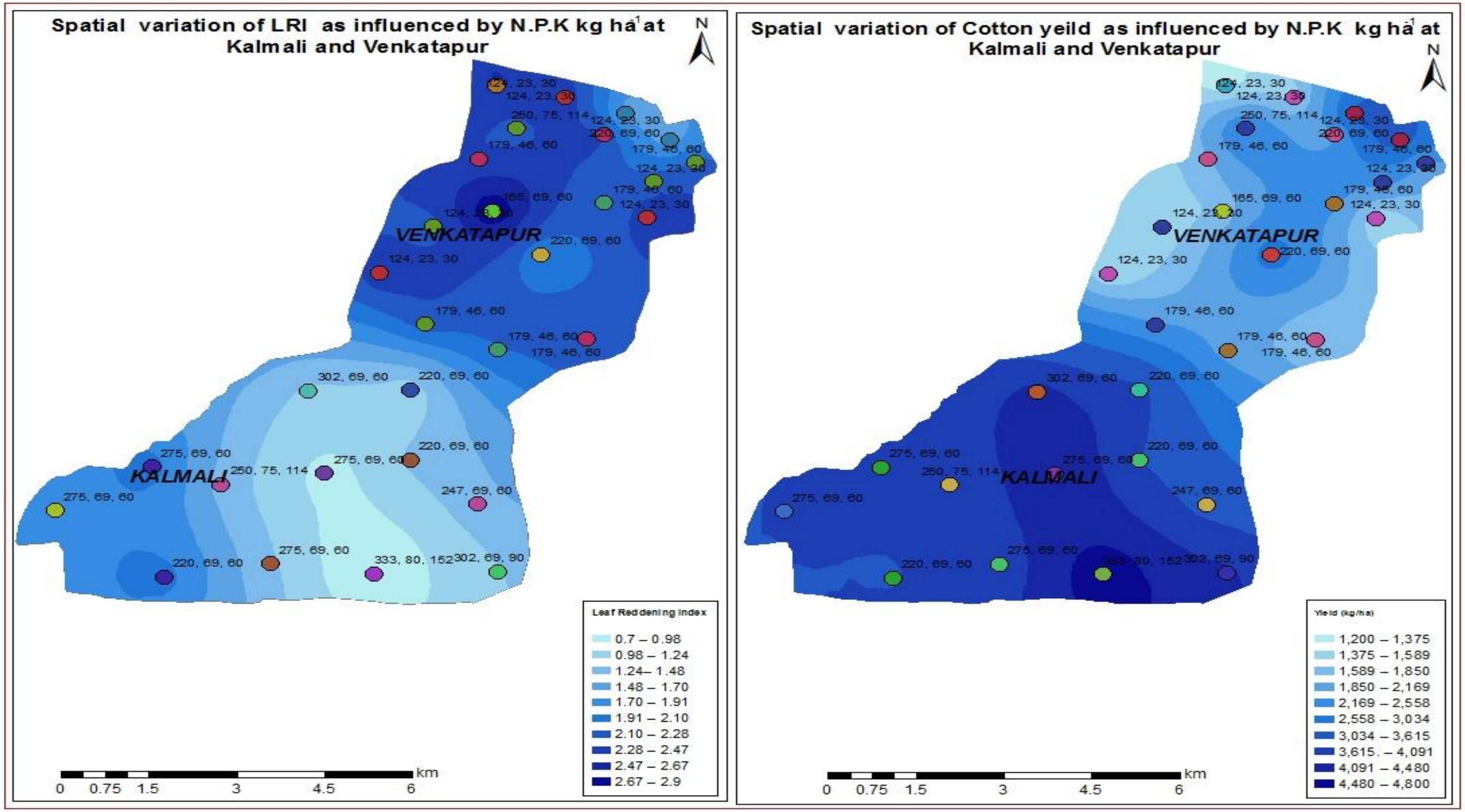

Fig. 6. Spatial variation of leaf reddening index and cotton yield with respect to fertilizer levels at Kalmala and Venkatapur village

4. CONCLUSION

From above the results of the study concludes the usefulness of spectral vegetation indices at critical stages of Bt cotton (flowering to boll development) for crop health and yield assessment in cotton. Similarly, earlier Chandrashekar et al. [6], Potdar [7] and Chetan and Potdar [8] revealed possibility of use of spectral indices for crop health assessment and yield forecast in sugar cane, pigeon pea and maize, respectively. Chetan and Potdar [8] also indicated that spectral indices namely SPAD at 55 DAS and NDVI at 60 DAS are the best indices for crop health and yield prediction. Further, these indices being non-distractive could also be obtained from satellite imagery and on-ground truthing would facilitate precision agriculture on large scale, and quality decisions by policymakers could be accomplished effectively as well.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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