International Journal of Agriculture and Plant Science
www.agriculturejournal.in
Online ISSN: 2664-7664
Received: 03-02-2026, Accepted: 04-03-2026, Published: 20-03-2026
Volume 8, Issue 1, 2026, Page No. 287-292

Spatial assessment of organic paddy (BPT-5204) cultivation suitability in Srikakulam District, Andhra Pradesh: A cluster-based field study

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Abstract
Srikakulam district in north coastal Andhra Pradesh is a historically significant paddy-growing region where the fine-grain variety BPT-5204 (Samba Mahsuri) has been cultivated for decades. Despite its agro-climatic suitability and consumer preference, systematic, spatial assessments of which areas within the district can support a transition to organic paddy cultivation have not been reported in the peer-reviewed literature. This study addresses that gap. Using secondary district-level agricultural statistics for 2019-20, mandals were ranked by paddy cultivated area and total production to identify priority zones. Primary data were collected from 500 paddy-growing farmers (minimum 2 acres land holding) across 15 purposively selected villages, grouped into two geographically compact clusters. Results identified three mandals Polaki, Srikakulam, and Narasannapeta, as the highest-priority zones, together accounting for the leading positions in both area and production among all 38 mandals. Within these mandals, 15 villages were mapped using GPS-aided QGIS and divided into two clusters of 7 and 8 villages, respectively. The socio-economic profile of the 500 sampled farmers reveals dominance of small and marginal landholders with SSC-to-Intermediate level schooling and small family sizes. Paddy is universal as the kharif crop; rabi diversification involves pulses and sesamum in Cluster-1 and paddy and pulses in Cluster-2. Canal-and-borewell irrigation predominates, and cattle ownership is significantly higher in Cluster-2 (78%) compared to Cluster-1 (60%). The study provides an evidence-based framework for delineating organic paddy cultivation zones and characterising the socio-economic context of prospective organic farmers.

Keywords: BPT-5204, organic paddy, Srikakulam, suitability assessment, spatial clustering, socio-economic profile, Andhra Pradesh

Introduction

Rice (*Oryza sativa* L.) is the primary dietary staple for over half of the world's population and a crop of enormous strategic importance to India's food security (Goswami *et al*., 2022) [5]. India holds the world's largest harvested area of rice at approximately 44 million hectares, accounting for nearly one-quarter of global rice production, and has long been among the world's leading rice exporters (Mishra *et al*., 2018) [12]. Andhra Pradesh, often described as the 'Rice Bowl of India', is one of the most productive rice-growing states in the country, with rice cultivation spread across 10.1 million hectares of cultivated area encompassing six agro-climatic zones (NITI Aayog, 2018) [13].

Within Andhra Pradesh, north coastal districts such as Srikakulam have historically specialised in the cultivation of fine-grain rice. The variety BPT-5204, popularly known as Samba Mahsuri, released in 1986, is a mega-variety now cultivated across an estimated 4 million hectares nationally (NRI Agritech, 2012) [14]. Its medium-slender grain, excellent cooking and eating quality, non-lodging and non-shattering characteristics, and suitability to canal-irrigated ecosystems have made it the preferred variety of both farmers and consumers in north coastal Andhra Pradesh (ICAR-IARI, 2021) [8]. However, BPT-5204 is notoriously susceptible to bacterial leaf blight, brown plant hopper, and blast, necessitating intensive chemical management that raises the cost of cultivation and compromises environmental sustainability (Wikipedia, 2024).

Against this background, there is growing interest from state governments, agri-businesses, and international development organisations in transitioning paddy cultivation in Andhra Pradesh towards organic or natural farming systems. The Andhra Pradesh Community Natural Farming (APCNF) programme, implemented through the Rythu Sadhikara Samstha (RySS), has been one of the world's largest agroecological transitions, targeting coverage of six million farming households (Pant *et al*., 2019; LaCanne & Lundgren, 2022; Daystar *et al*., 2025) [3, 11, 16]. Independent field evaluations in Andhra Pradesh have shown that Zero Budget Natural Farming (ZBNF) the core practice set of APCNF can achieve paddy yields comparable to conventional systems while significantly reducing input costs (LaCanne & Lundgren, 2022) [11]. A study of 285 crop-cutting experiments in paddy fields found ZBNF plots averaging 6,417 kg/ha compared to 5,816 kg/ha in non-ZBNF fields (Tufts CREATE, 2021) [21].

Yet, while the policy and programmatic landscape for organic or natural rice farming in Andhra Pradesh is relatively well described, there is a notable absence of published, field-based studies that spatially delineate which areas within a given district are best suited for organic paddy cultivation, and that systematically profile the socio-economic characteristics of farmers in those areas. Such information is indispensable for the rational planning of organic farming transitions, grower-group formation, and certification cluster design, particularly under the National Programme for Organic Production (NPOP), which requires geographically compact grower groups for efficient internal control system (ICS) management.

This study was conducted in Srikakulam district with the specific objectives of: (i) identifying, from secondary data, the mandals and villages with the highest potential for organic paddy cultivation; (ii) delineating geographically compact clusters suitable for collective organic certification; and (iii) characterising the socio-economic profile including age, education, land holding, family size, cropping pattern, irrigation source, and cattle ownership of paddy farmers in the identified areas. The findings are intended to provide an evidence base for researchers, extension workers, and policy planners involved in designing organic paddy farming programmes in comparable coastal deltaic districts of India.

Literature Review

The agronomic and socio-economic dimensions of organic rice farming have received increasing scholarly attention in recent decades. Hazra *et al.* (2018) [7], in a comprehensive review of organic rice production strategies, identified nitrogen stress during critical growth stages, non-availability of rapidly mineralisable organic amendments, and weed competition as the principal yield-limiting constraints in organic paddy systems. They emphasised that diverse organic nutrient sources including fast-mineralising manures, green manures, and biofertilisers applied in split doses can sustain adequate yields in organic rice cultivation.

The socio-economic determinants of organic farming adoption have been examined across multiple contexts. Suswadi and Kartikasari (2021) [20], in their study of organic rice farmers in Indonesia, found that age, education level, farming experience, family size, and land holding area are the key socio-economic variables influencing adoption decisions. They noted that relatively younger, better-educated farmers with larger land holdings are more receptive to organic transitions. Samarpitha *et al.* (2014) [19], studying rice farmers in Kurnool district of Andhra Pradesh a district ecologically comparable to Srikakulam found that educational profile and farm size significantly influenced technology adoption behaviour, while age influenced risk-taking attitudes.

On the constraints side, Ghanghas *et al.* (2021) [4] studied organic farming farmers in Haryana and found that the predominance of inorganic farmers in the vicinity was the top-ranked constraint, followed by low production during the conversion period and the lack of agencies to purchase organic produce. Haneef *et al.* (2019) [6] identified initial yield loss and inadequate credit availability as the foremost economic constraints, alongside lack of training institutions and indigenous certification agencies as infrastructural bottlenecks. Kalirajan and Supriya (2019) [10], studying farmers in Tamil Nadu, ranked labour scarcity as the most serious physical constraint and lack of training as the foremost communication constraint findings that are directly comparable to the Srikakulam context.

In the specific context of Andhra Pradesh, Goswami *et al.* (2022) [5], in a study of 500 conventional and 500 natural farming rice-growing farmers, identified higher labour costs, lack of experience in agroecological techniques, low soil fertility, and pest incidence as critical constraints to natural farming adoption. Pant *et al.* (2019) [16], documenting the ZBNF programme's rollout in Andhra Pradesh, reported statistically significant yield and income advantages for ZBNF-practising farmers relative to conventional counterparts across multiple crops and locations. More recently, Daystar *et al.* (2025) [3], publishing in Nature Ecology and Evolution, confirmed positive outcomes on crop yields, farmer income, and bird species abundance from the APCNF programme using causal inference methods, while noting that outcomes were context-dependent.

Research on the spatial dimensions of organic farming suitability has been less common. Balan *et al.* (2015) [2] used clustering methods to identify viable organic farming zones and demonstrated the utility of considering farm sizes and agricultural profiles in cluster delineation. Park *et al.* (2018) [17] illustrated how combining remote-sensing data with land-use variables can support paddy classification and mapping at a fine spatial resolution. In India, the formation of geographically compact grower clusters has been recognised as a prerequisite for cost-effective organic certification under the ICS model, yet field-based studies systematically documenting the process of cluster delineation are sparse in the literature.

Oinam and Sudhakar (2014) [15] found that the majority of paddy farmers in Manipur applied recommended organic input quantities in their nurseries, highlighting that basic organic management practices are not entirely unfamiliar to smallholders. Roy *et al.* (2013) [18], studying the socio-economic status of hill farmers in Uttarakhand, found that small landholding size, medium education levels, and subsidiary occupations characterised marginal farming communities a profile similar to what this study encountered in Srikakulam. The present study therefore builds on and extends this body of knowledge by providing a systematic spatial and socio-economic assessment for a specific agro-ecosystem in north coastal Andhra Pradesh.

Materials and Methods

1. Study Area

The study was conducted in Srikakulam district, the northernmost district of Andhra Pradesh, situated between 18°20' and 19°10' N latitude and 83°40' and 84°47' E longitude. The district covers an area of 5,837 sq. km and is bounded by Vizianagaram district to the south and west, the state of Odisha to the north, and the Bay of Bengal to the east. It is administratively divided into 38 mandals encompassing 1,865 villages. Agriculture is the dominant economic activity, with paddy as the lead crop occupying 2,14,662 hectares under kharif cultivation in 2019. The district has eight agricultural divisions and is served by significant irrigation infrastructure, including the Vamsadhara Stage-1 (gross irrigated area: 59,988 ha), Vamsadhara Stage-2 (33,298 ha), and the Narayanapuram project (14,995 ha). Red soil is the predominant soil type (58.6% of total area), followed by brown forest soil (14.6%) and alluvial soil (10.3%). The net sown area in 2018-19 was 3,07,438 ha with a cropping intensity of 140 per cent.

2. Data Sources

Secondary data on mandal-wise paddy cultivated area (ha) and production (metric tonnes) for 2019-20 were obtained from the office of the Joint Director of Agriculture (JDA), Srikakulam. Supplementary secondary data on land utilisation, irrigation sources, and major crop statistics (2018-19) were also sourced from the JDA. Primary data were collected from 500 paddy-growing farmers using a pre-tested semi-structured interview schedule. The period of data collection was February to June 2022.

3. Sampling Design

A two-stage purposive sampling strategy was employed. In the first stage, mandals were ranked by paddy area and production using secondary data; the top three mandals on both criteria were selected. In the second stage, mandal agricultural officers were consulted and 15 villages out of the 120 total in the three mandals were purposively selected based on the established prevalence of BPT-5204 cultivation. The sampling unit was a paddy-growing farmer with a minimum land holding of 2 acres, as organic certification under NPOP requires documentation that is practicable only above this threshold. Within each village, farmers meeting this criterion were enumerated and constituted the sampling frame. Five hundred farmers were selected proportionally across the 15 villages.

4. Cluster Delineation

To form geographically compact blocks suitable for collective organic certification a prerequisite under NPOP's Internal Control System for small farmer groups the 15 selected villages were divided into two spatial clusters based on their geographical proximity, using QGIS (Quantum Geographic Information System) software. Geographic coordinates of each village were recorded using the Maverick GPS application in the World Geodetic System 1984 (WGS84) reference frame. Villages that formed a contiguous spatial group were designated as Cluster-1 or Cluster-2. Cluster-1 (7 villages) comprises villages from Srikakulam and Narasannapeta mandals, while Cluster-2 (8 villages) comprises villages from Narasannapeta and Polaki mandals.

5. Analytical Methods

Secondary data were analysed using tabular analysis and ranking. Primary data on socio-economic characteristics, cropping patterns, irrigation sources, and cattle ownership were analysed using frequencies and percentages. All categorical variables are reported as frequency counts and percentages stratified by cluster to allow direct inter-cluster comparisons.

Results and Discussion

1. Identification of Priority Mandals

Secondary data from all 38 mandals in Srikakulam district were ranked by paddy area and production. The three mandals ranked highest on both metrics were Polaki (Rank 1 by area: 8,516 ha; Rank 1 by production: 39,864 MT), Srikakulam (Rank 2 by area: 8,322 ha; Rank 3 by production: 34,084 MT), and Narasannapeta (Rank 3 by area: 7,846 ha; Rank 2 by production: 38,605 MT). These three mandals collectively accounted for a substantial share of the district's paddy output and were therefore selected as the study area. Table 1 presents the comparative ranking.

Table 1: Top Three Mandals by Paddy Cultivated Area and Production in Srikakulam District (2019-20)

Mandal	Area (ha)	Area Rank	Production (MT)	Production Rank
Polaki	8,516	1	39,864	1
Srikakulam	8,322	2	34,084	3
Narasannapeta	7,846	3	38,605	2

Source: JDA Office, Srikakulam District (2019-20).

2. Village Selection and Cluster Delineation

From the 120 villages across the three mandals, 15 villages were identified where BPT-5204 was the predominant or co-dominant variety. These were divided into two clusters. Cluster-1 (261 farmers, 7 villages) encompasses Bhyri, Boddavalasa, Devadi, Kambakaya, Karajada, Makivalasa, and Narayanavalasa all in Srikakulam and Narasannapeta mandals. Cluster-2 (239 farmers, 8 villages) encompasses Deerghasi, Dola, Dubbakuvanipeta, Gollalavalasa, Gopalapenta, Mallavanipeta, Pothayyavalasa, and Talasamudram in Narasannapeta and Polaki mandals. The distribution of sampled farmers across mandals and clusters is shown in Table 2.

Table 2: Distribution of Sampled Farmers across Clusters and Mandals

Mandal	Cluster-1 (n)	Cluster-2 (n)	Total
Srikakulam	100	0	100
Narasannapeta	161	70	231
Polaki	0	169	169
Total	261	239	500

Source: Field survey data (2022).

3. Socio-Economic Profile of Sampled Farmers

3.1. Age Profile

Age is a well recognised determinant of risk tolerance, technology adoption propensity, and physical capacity in farming (Suswadi & Kartikasari, 2021) [20]. In Cluster-1, the majority of farmers (59.4%) were above 50 years of age, indicating an older farming demographic. In Cluster-2, the majority (59.8%) belonged to the 30-50 year cohort, suggesting a comparatively younger and potentially more innovation-receptive farming population. Farmers below 30 years of age were negligible in both clusters (1.9% and 2.5% respectively), consistent with the broader trend of youth disengagement from agriculture in India.

Table 3: Age Profile of Sampled Farmers by Cluster

Age Category	Cluster-1 (n)	Cluster-1 (%)	Cluster-2 (n)	Cluster-2 (%)
Below 30 years	5	1.9	6	2.5
30–50 years	101	38.7	143	59.8
Above 50 years	155	59.4	90	37.7
Total	261	100.0	239	100.0

Source: Field survey data (2022).

3.2. Family Size

Family size has a dual relevance in the organic farming context: it determines both the availability of unpaid family labour critical for labour-intensive organic practices such as manual weeding and the marketable surplus available for sale after household consumption. In both clusters, small families (1-4 members) predominated: 61.3% in Cluster-1 and 65.7% in Cluster-2. Medium-sized families (5-7 members) comprised 32.2% and 29.7% respectively, while large families (>7 members) were rare at 6.5% and 4.6%. The preponderance of small families constrains the family labour pool available for organic practices, a concern that intersects with the labour scarcity problem discussed in related literature for the region (Goswami *et al.*, 2022) [5].

3.3. Educational Profile

Educational attainment influences farmers' ability to comprehend organic certification documentation, understand contractual obligations, and assimilate technical training on organic inputs. The largest category in both clusters was SSC to Intermediate (42.9% in Cluster-1; 39.3% in Cluster-2), followed by Below SSC (30.7%; 30.5%). Illiteracy rates were 16.9% and 16.3% respectively. Graduates and above accounted for only 9.6% (Cluster-1) and 13.8% (Cluster-2). While functional literacy is adequate for basic certification compliance, the low graduate population suggests a need for simplified, vernacular-medium training materials and continuous extension support. These findings align with Samarpitha *et al.* (2014) [19], who observed similar educational distribution patterns among rice farmers in Kurnool, Andhra Pradesh.

Table 4: Educational Profile of Sampled Farmers by Cluster

Education Level	Cluster-1 (n)	Cluster-1 (%)	Cluster-2 (n)	Cluster-2 (%)
Illiterate	44	16.9	39	16.3
Below SSC	80	30.7	73	30.5
SSC to Intermediate	112	42.9	94	39.3
Graduate and above	25	9.6	33	13.8
Total	261	100.0	239	100.0

Source: Field survey data (2022).

3.4. Land Holding Pattern

The land holding structure of the sampled farmers reflects the broader agrarian situation in coastal Andhra Pradesh, dominated by small and marginal cultivators. Small farmers (1-2 ha) were the largest category in both clusters: 45.6% in Cluster-1 and 54.9% in Cluster-2. Marginal farmers (<1 ha) constituted 40.6% and 39.3% respectively. Semi-medium farmers (2-4 ha) were 12.3% and 6.3%. Medium farmers (4-10 ha) constituted only 1.5% in Cluster-1 and were entirely absent in Cluster-2. No large farmers (>10 ha) were present in either cluster. The small farm sizes create both a constraint and an opportunity for organic certification: while per farm documentation costs are higher, the NPOP group certification model which allows grower groups of 25-500 farmers can overcome this barrier through collective management under an ICS (APEDA, 2020-21) [1].

Table 5: Land Holding Distribution of Sampled Farmers by Cluster

Land Holding	Cluster-1 (n)	Cluster-1 (%)	Cluster-2 (n)	Cluster-2 (%)
<1 ha (Marginal)	106	40.6	94	39.3
1–2 ha (Small)	119	45.6	130	54.9
2–4 ha (Semi-medium)	32	12.3	15	6.3
4–10 ha (Medium)	4	1.5	0	0.0
>10 ha (Large)	0	0.0	0	0.0
Total	261	100.0	239	100.0

Source: Field survey data (2022).

4. Cropping Pattern

Paddy is the universal kharif crop across all 500 sampled farms in both clusters, with 12 and 18 farmers in Clusters 1 and 2 respectively growing sugarcane as an additional kharif crop. In rabi, the dominant crops are green gram and black gram grown by 199 (76.3%) and 210 (87.9%) farmers in Clusters 1 and 2 respectively. Sesamum is the second major rabi crop in Cluster-1 (117 farmers; 44.8%), while paddy itself assumes this role in Cluster-2 (110 farmers; 46.0%). In summer, the majority of farmers either leave fields fallow (200 and 227 farmers in Clusters 1 and 2) or grow hybrid pulses (164 and 116 farmers respectively). The dominant observed cropping patterns are summarised in Table 6.

Table 6: Major Cropping Patterns Observed in the Study Area

Rank	Cluster-1 Cropping Pattern	Cluster-2 Cropping Pattern
1	Paddy – Pulses – Sesamum	Paddy – Pulses – Hybrid Pulses
2	Paddy – Sesamum – Hybrid Pulses	Paddy – Paddy – Fallow
3	Paddy – Paddy – Fallow	Paddy – Sesamum – Hybrid Pulses / Fallow

Note: Seasons listed in order: Kharif – Rabi – Summer.
Source: Field survey data (2022).

5. Source of Irrigation

The major irrigation sources in both clusters are combinations of borewells and canals, or canals alone. In Cluster-1, 127 farmers (48.7%) rely on borewells and canals in combination; 70 (26.8%) depend exclusively on canals; and 56 (21.5%) rely solely on borewells, primarily in Bhyri village. In Cluster-2, 119 farmers (49.8%) use a borewell-canal combination; 74 (31.0%) depend solely on canals; and 32 farmers (13.4%) in Pothayyavalasa depend on canals and rainfall, as canal water reaches this village only in the month of August. Canal-dependence is somewhat higher in Cluster-2, suggesting greater vulnerability to seasonal variability in canal supply. The dominance of canal irrigation across the study area, served by the Vamsadhara Stage-1 and Stage-2 projects, provides a stable water base for kharif paddy cultivation in both clusters.

6. Cattle Ownership

Cattle ownership is a critical enabling factor for organic paddy cultivation, as it provides on-farm access to cattle dung and urine the primary raw materials for key ZBNF bio-inputs such as jeevamrutha (jiwamrita), beejamrutha (bijamrita), and farmyard manure (FYM). In Cluster-1, 60% (157 of 261) of farmers owned cattle; in Cluster-2, this proportion rises significantly to 78% (187 of 239 farmers). The higher cattle density in Cluster-2 confers a structural advantage for organic bio-input preparation and FYM production. This finding is consistent with observations by Goswami *et al.* (2022) [5] that access to cattle is a key enabler of natural farming adoption in Andhra Pradesh, and parallels the findings of Roy *et al.* (2013) [18] on the role of livestock assets in determining agricultural livelihood strategy.

Conclusions

This study presents a systematic, evidence-based methodology for spatially identifying zones suitable for organic paddy cultivation and characterising the farming community within those zones, using Srikakulam district of Andhra Pradesh as a case study. Three mandals Polaki, Srikakulam, and Narasannapeta were identified as the highest-priority areas based on paddy area and production data. Within these mandals, 15 villages were delineated into two geographically compact clusters using GPS-aided QGIS mapping, providing a spatial framework suitable for NPOP group certification.

The socio-economic profile of the 500 sampled farmers reveals a landscape typical of smallholder coastal rice agriculture in India: dominance of small and marginal landholders, moderate educational attainment concentrated at the SSC-to-Intermediate level, small family sizes, and dependence on canal-borewell irrigation. Paddy is universal as the kharif crop, with rabi diversification involving pulses and oilseeds. Cattle ownership a key proxy for organic input readiness is substantially higher in Cluster-2 (78%) than in Cluster-1 (60%).

These findings have several practical implications. First, both clusters present viable spatial units for organic certification under the NPOP ICS model, given their geographical compactness and shared agronomic context. Second, Cluster-2 has a structural advantage in organic input preparation due to higher cattle ownership, while Cluster-1 may benefit from stronger extension support to build FYM and bio-input capacity. Third, the older age profile of Cluster-1 farmers and the lower educational attainment across both clusters underscore the need for farmer-friendly, vernacular-medium extension systems such as the Community Resource Person model used by RySS in its APCNF programme. This study provides a replicable methodological framework for spatial suitability assessment that can be applied to other districts and crops in India's organic farming transition.

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