

# Distribution of Nutrients in the Soils of a Unique Tropical Agroecosystem

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**Abstract.** Kuttanad agroecosystem, once the rice bowl of Kerala, is facing a serious threat from human activities. The present study assessed the nutrient status of Kuttanad paddy soils and the spatial distribution of Nutrients using GIS technique. 117 soil samples were collected from the six agroecological zones of Kuttanad. Out of the 117, 92 were from paddy fields and 25 were from canals. The soil samples were analyzed for pH, organic Carbon (%), available nitrogen (kg/ha), available phosphorous (kg/ha) and available potassium (kg/ha). The spatial distribution of nutrients showed that high available nitrogen content was observed at various parts of the Kuttanad agroecosystem except Vaikom Kari, northern part of North Kuttanad and western part of Kayal Lands. A cluster of area including southeast region of Lower Kuttanad, northern part of Purakkad Kari and north east regions of Upper Kuttanad as well as north east part of Vaikom Kari has showed the highest concentration of phosphorous. High intensity of potassium was observed in the central portion of Kayal Lands, North Kuttanad, northeast and southeast regions of Purakkad Kari and Lower Kuttanad respectively. It can conclude that monsoon flooding has a major role in the regulation of nutrients in the Kuttanad paddy fields. N and P are taken away from the soil by the inundated water whereas potassium is deposited in these areas. The high concentration of nutrients observed at the sites which are having more than one time cultivation and also watering and dewatering has a significant role in regulating the nutrient status of the Kuttanad agricultural wetland ecosystem.

**Key words:** Agroecosystem, Kuttanad, monsoon flooding, nutrient distribution, one time cultivation

## 1 Introduction

Acquiring detailed knowledge about the soil fertility status is a prerequisite for assessing the long-term impact of modern, intensive rice production technologies on paddy soils. Due to negative nutrient balances, significant depletion of soil nutrients such as potassium or phosphorous seems to occur in irrigated rice areas of tropical Asia [1, 2, 3]. Soil fertility deals with nutrient status and ability of soil to supply nutrients for optimum plant growth. However, the optimum nutrient status alone will not ensure soil productivity [4].

Soil characteristics are highly variable due to the combined effects of physical, chemical and biological processes that operate with different intensities and [5]. The spatial variability of soil properties is influenced by both intrinsic (soil formation factors, such as soil parent materials) and extrinsic agricultural management practices, such as fertilization and irrigation) factors [6]. Uniform management of fields often results in over-application of inputs in areas with high nutrient levels and under-application in areas with low nutrient levels [7]. Besides natural landscape conditions, proper management and practices for highly productive paddy soils are characterized by high inputs of agricultural chemicals, e.g., chemical fertilizers. However, the amount of soil nutrients that moves through the environment, closely correlate with the soil nutrient contents and the applied fertilizers [8, 9].

The Kuttanad rice agroecosystem extends from 9° 17' – 9° 40' N and 76° 19' – 76° 33' E and is a unique system situated 0.6 – 2.2 m below mean sea level (msl). It is the delta of four major river systems in Kerala. It measures approximately 25 km east to west and 60 km north to south on the west coast of Kerala, in which about 53,639 hectares are used for rice cultivation. Much of this region remains water-logged almost throughout the year and is subjected to continued flood submergence during the monsoon and saline water ingress during the summer months [10] even though the Thanneermukkom

barriage restrict the flow of saline water into the Kuttanad. The restriction of saline water caused for the decrease in flush out which was earlier regulated the nutrient dynamics. Most of these fields are inundated during the non-crop season and water has to be pumped out to the canal systems and backwaters before the commencement of the cultivating season [11].

The current knowledge about nutrient balances and soil fertility status in entire Kuttanad rice agroecosystems is less. Kuttanad agroecosystem, once the rice bowl of Kerala, is facing a serious threat from human activities. The indiscriminate use of chemical fertilizers in paddy fields and the Thannermukkom barrage influenced the nutrient dynamics of Kuttanad. A very few studies have been reported on the status of such a unique agroecosystem. Hence the present study assessed the nutrient status of Kuttanad paddy soils and the spatial distribution of Nutrients using GIS technique.

## 2 Materials and Methods

### 2.1 Sampling

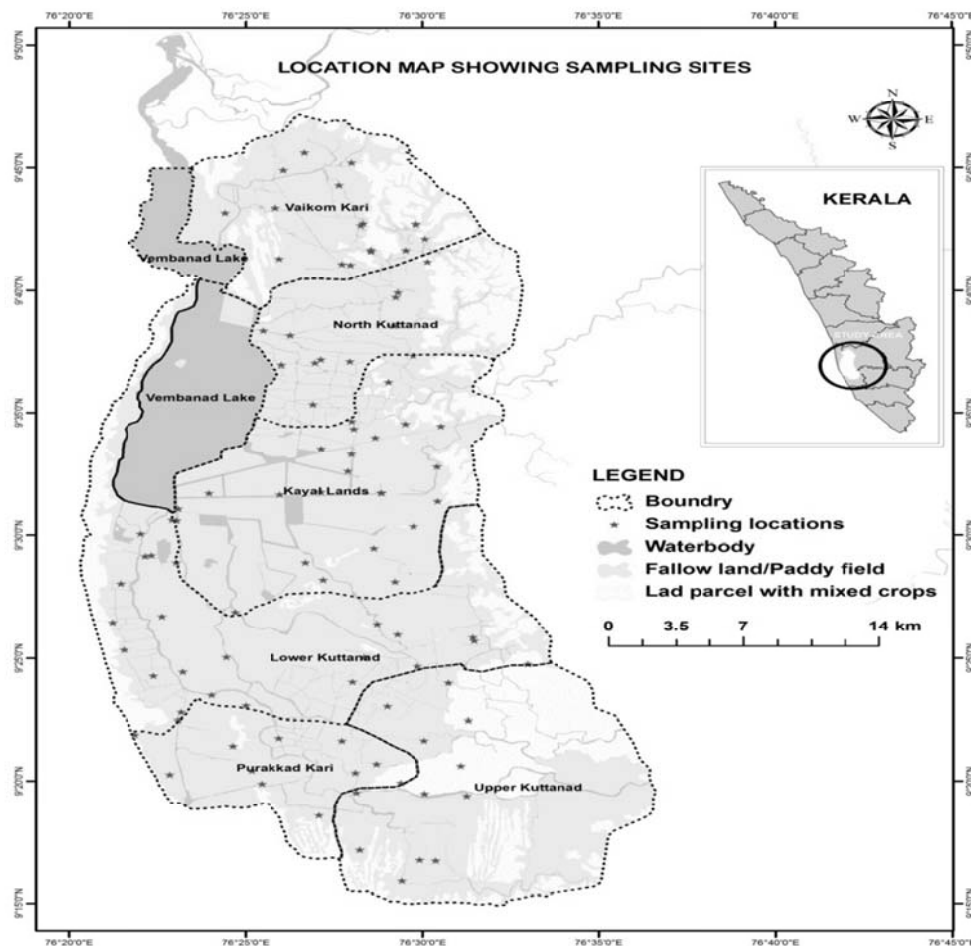


Figure 1. Study area map

For the collection of soil samples, Stratified random sample technique was used. Sampling sites were selected so as to represent the total amount of whole study area (Figure1). The soil samples were collected from 117points at 10-15 cm depth from each site. The grid size is 5 km×5 km. The exact

sample location was recorded using a Global Positioning System (GPS).

## 2.2 Sample Preparation

In the lab, soil samples were air dried and then ground to fine powder using an agate mortar. Then the samples were separated to granulometric fraction, <200 $\mu$  using ASTM sieves and this fraction was used for the chemical analysis. The correlations between parameters were statistically analyzed by the software SPSS.

## 2.3 Chemical Analysis

The pH was measured by digital pH meter. Soil nutrients such as Organic carbon, Nitrogen, Phosphorus and Potassium were analyzed by following methods:

- Organic Carbon-Walkley and Black Rapid titration method [12]
- Nitrogen- Alkaline Potassium permanganate method [13]
- Phosphorous-Bray's Method [14]
- Potassium-Morgan's extraction method [14]

The soil fertility maps were prepared using Arc GIS 9.3 software.

## 3 Results

The pH of the Kuttanad paddy soil was slightly acidic and ranged from 2.47-5.16 with a mean of 3.97 (Table 1). The Canal sediments of Kuttanad were also acidic ( $3.73 \pm 0.69$ ). Maximum soil organic carbon recorded for the paddy fields is 16.6% where as in Canal it was 13.03% and the mean value recorded was 4.72% and 6.20% respectively. The Available N content of the Kuttanad soils ranged from 378 kg/ha to 1386 kg/ha with a mean of 771.91 kg/ha and Av.N content in the canal sediment ranged from 378 to 1386 kg/ha with a mean of 781.2 kg/ha (Table 2). The maximum concentration of Av.P in the paddy fields of Kuttanad was 5.42 kg/ha whereas the minimum concentration observed was 0.018 kg/ha. The canal sediments showed a range of 0.018 to 3.942 kg/ ha with a mean of 0.71 kg/ha for Av.P. The Av.K content varied from 29.12 kg/hato 884.8 kg/ha.

**Table 1.** Physico-chemical and nutrient concentration of soil samples collected from the paddy fields of entire kuttanad

	pH	OC (%)	OM (%)	Av.N (Kg/ha)	Av.P (Kg/ha)	Av.K (Kg/ha)	BD (gm/cm <sup>3</sup> )
Minimum	2.47	0.9	1.552	1.552	378.00	0.018	29.12
Maximum	5.16	16.6	28.618	28.618	5.420	5.420	884.80
MEAN	3.97	4.72	8.140	771.910	0.71	322.320	0.60
SD	0.56	2.59	4.460	218.720	1.27	142.940	0.21

**Table 2.** Physico-chemical and nutrient concentration of soil samples collected from the canals of entire kuttanad

	pH	OC (%)	OM (%)	Av.N (Kg/ha)	Av.P (Kg/ha)	Av.K (Kg/ha)
Minimum	1.64	1.94	3.345	378	0.018	23.52
Maximum	4.74	13.03	22.464	1386	3.942	1288
MEAN	3.73	6.20	10.690	781.2	0.710	326.41
SD	0.69	2.87	4.950	302.14	1.240	276.91

The mean Av.N concentration (771.91 kg/ha) of paddy fields comes under high fertile classification (Table 3). Among the total 92 sites, 15 sites are coming under the medium fertility class (272-544kg/ha) and the others fall within high fertile class (77sites) depending on the nitrogen availability. The 84% of

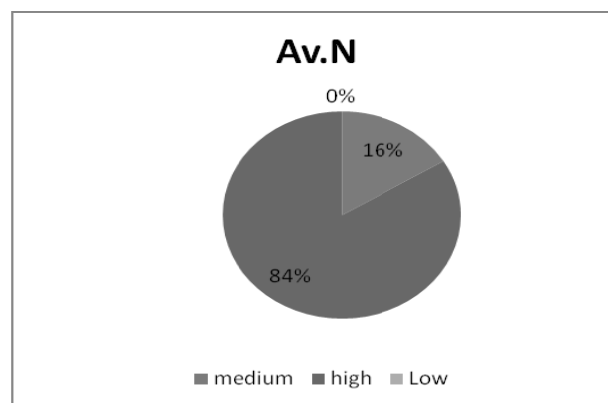
total soil sample was highly fertile in terms of nitrogen and other 16% came under medium fertile class. Exceptionally high Nitrogen content in some sites is due to the indiscriminate use of fertilizers by the farmers.

**Table 3.** Standard soil fertility classification based on nutrient content

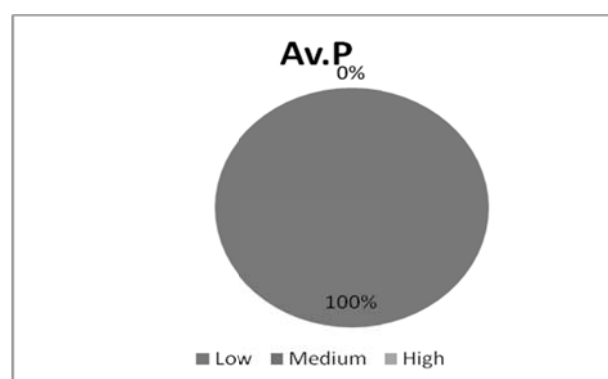
Status	Av.N (kg/ha)	Av.P (kg/ha)	Av.K (kg/ha)
Low	<272	<9.8	<120
Medium	272-544	9.8-24.5	120-280
High	>544	>24.5	>280

The Av.P content of entire Kuttanad was coming under low fertility class. The mean value of Av.P (0.708 kg/ha) indicated that the entire Kuttanad paddy fields are low fertile in terms of phosphorus content (Fig 7). Similar results in acidic soils were also observed by [15, 16, 17]. Available phosphorus increases with pH and decreases with organic carbon and there will be conversion of water soluble inorganic phosphorus into unavailable form during the decomposition of organic residues of wide C: P ratio [18].

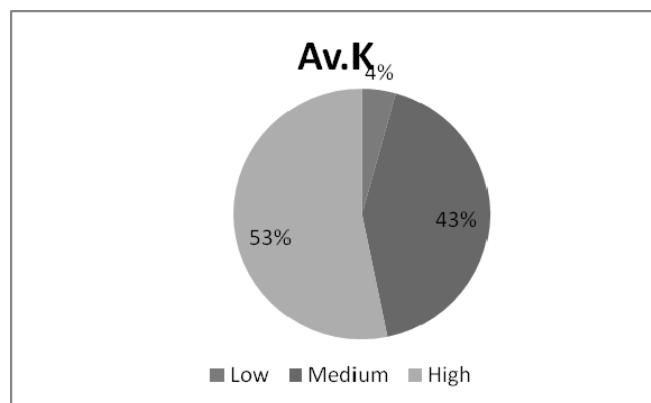
Considering the potassium content, 3 sites were coming under the low fertility class (<120), others are distributed between medium (14 sites) and high (75 sites) fertility classes. Hence the mean value (326.41kg/ha) showed that the entire Kuttanad paddy fields are highly fertile in terms of Av. K. Potassium was distributed in all the three classes of fertility and the lowest percentage of occurrence noticed for low fertility (4%). 43% of the sample represented medium class while considering the potassium content, whereas 53 % was under highly fertile class and only 4% is under low fertility (Figure 4). Earlier studies observed that low pH content is related to low potassium conte.



**Figure 2.** Classification of soil samples based on standard N fertility class



**Figure 3.** Classification of soil samples based on standard P fertility class



**Figure 4.** Classification of soil samples based on standard K fertility class

The results showed that the soils of Kuttanad paddy field are highly acidic. This might be due to the partial decomposition of organic matter accumulated in the system locally known as 'kari' (acid sulphate enriched with iron) nature of the soil [21, 22]. The occurrence of acid sulphate soil in the west coast of Kerala, comprises kari and kayal soil depending on their location [23]. The major factors governing the pH of the soil include the concentration of reduced iron, manganese, hydroxides, carbonates, carbonic acids, and humic acids [24]. The present study also showed the negative correlation of pH with organic carbon.

The soil organic carbon and organic matter content recorded for Kuttanad paddy fields is also high. The return of rice straw into soil was considered to be the main reason for the increase in soil OC [8]. 50% of the straw biomass is buried in the sediments, which later decomposes to release the nutrients like nitrogen, phosphorous and potassium to the sediments [25]. OC improves cation exchange and supplies nutrients such as nitrogen and phosphorous [26]. The available nitrogen content of the Kuttanad soils was high (mean 771.91 kg/ha). OC and N are positively correlated in this study but not significant.

The concentration of available P in Kuttanad is very low. Phosphates in wetlands are easily taken up by the aquatic plants [27]. The higher the soil acidity, the larger the immobilization of P added in soils. Change in available nutrient contents was related with fertilizer applications, which were also influenced by soil properties [28]. The growth of aquatic plants for a long time during the flooding might be major reason for the lower P content in the Kuttanad soil.

The Av.K content of the soil of Kuttanad agroecosystem is also high. Studies have showed that application of rice straw significantly increased available K by increasing organic matter contents. Soil organic matter played a major role in holding and supply of K.

### 3.1 Spatial Dispersion of Nutrients in Kuttanad

The spatial distribution map of available N (Figure 5) shows that high available nitrogen content was observed at various parts of the kuttanad agroecosystem except Vaikom kari, Northern part of North Kuttanad and Western part of Kayal Lands. This might have owed to the monsoon flooding of the region. The regions with low content of available nitrogen having monsoon flooding, might have caused the dissolution of available N from the soil to water column. A cluster of areas including Southeast region of Lower Kuttanad, northern part of Purakkad Kari and North east regions of Upper Kuttanad as well as North east part of Vaikom kari have showed the highest concentration of phosphorous (Figure 7). Here also we can suspect the role of monsoon flooding in this mode of distribution. Available Potassium (Figure 6) showed an entirely different pattern. The central portion of Kayal lands, North Kuttanad, Northeast and southeast corner of Purakkad Kari and Lower Kuttanad have high intensity of potassium occurred. The high intensity regions of potassium were present where the intensity of Av P and Av N were low.

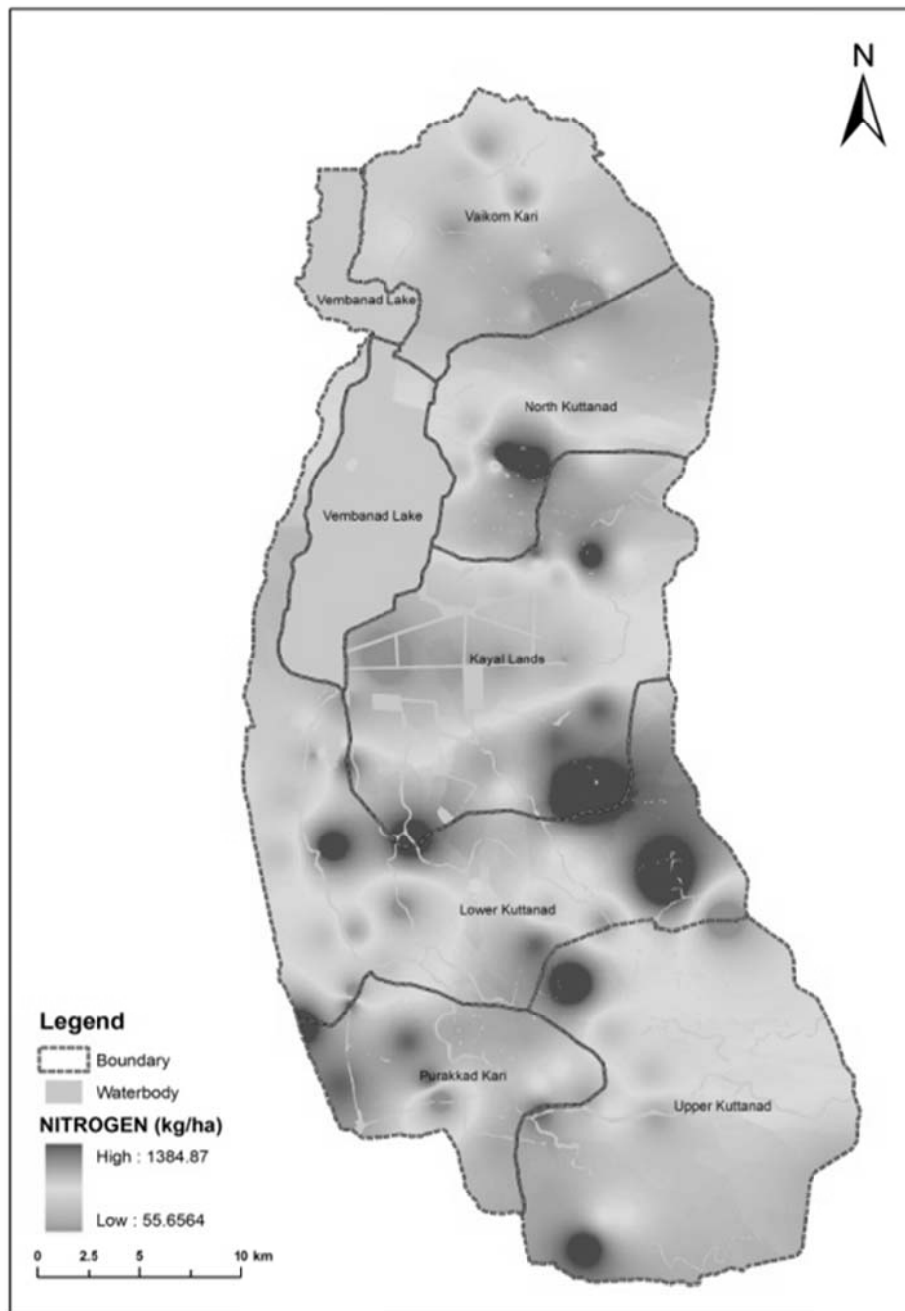


Figure 5. Spatial distribution map of available N

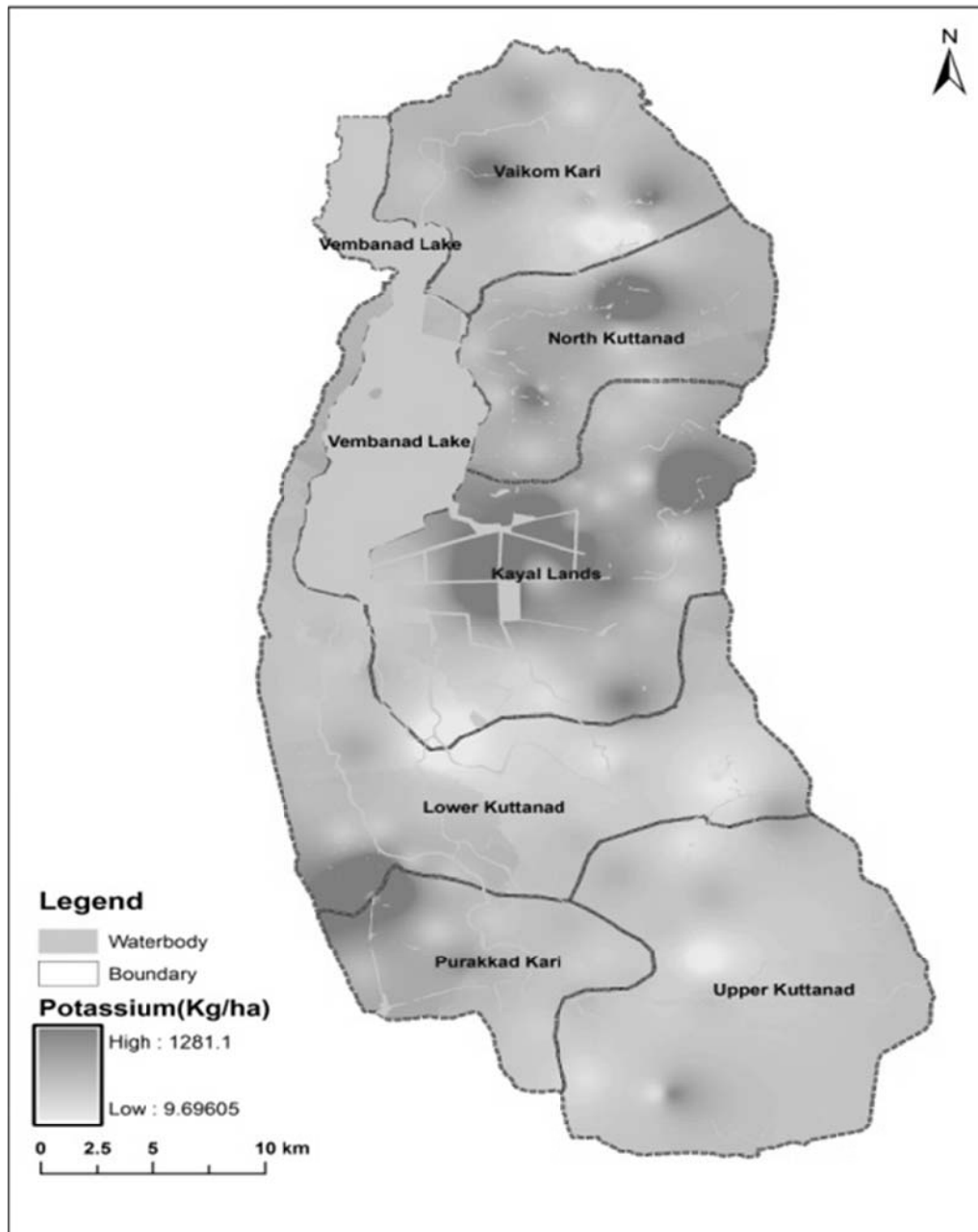
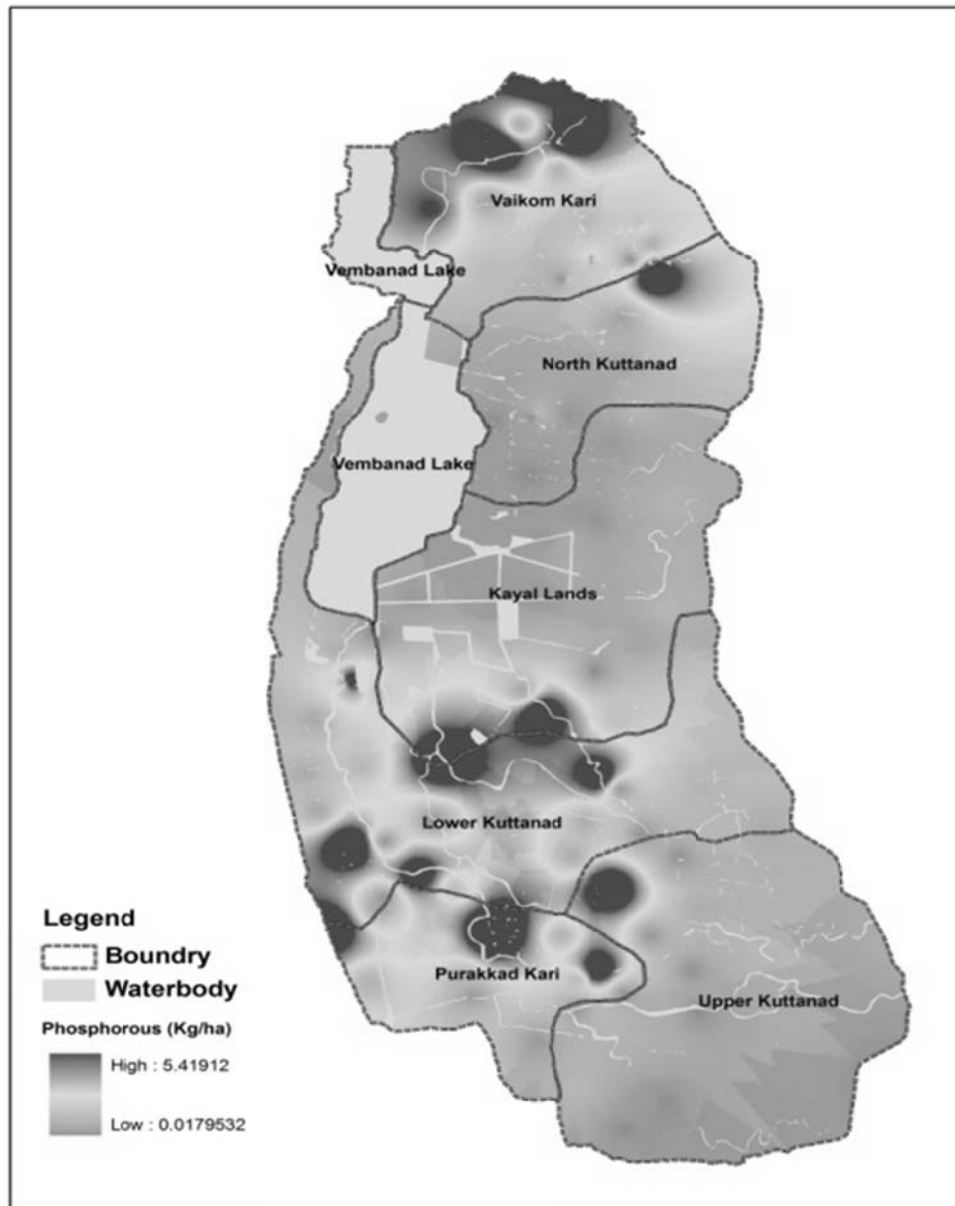


Figure 6. Spatial distribution map of available Potassium



**Figure 7.** Spatial distribution map of available Phosphorous

The monsoon flooding will have a significant role in regulation of nutrients in the Kuttanad paddy fields as it is flushed by fresh water from major four rivers of Kerala. Also the reduced flushout during summer season due to Thanneermukkom barrage may influence the nutrient dynamics of the system. N and P are taken away from the soil by the inundated water whereas potassium is deposited in these areas.



## 4 Conclusion

The soils of Kuttanad paddy fields are highly acidic, rich in organic matter and organic carbon. The soils are highly fertile in terms of available nitrogen and potassium contents and low fertile in terms of available phosphorous content. The spatial distribution of nutrients showed that N and P are low at sites where the condition is longtime flooding. The high concentration of nutrients was observed at the sites which are having more than one time cultivation. The results showed that the watering and dewatering has a significant role in regulating the nutrient status of the Kuttanad agricultural wetland ecosystem.

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