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Research Paper

Soil Site suitability of Major crops in Gangetic alluvial soils under Agro-climatic Sub-Region-15.1 – A case study under IBM-IORF Sustainability Program at Nadia, West Bengal, India

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Abstract: The primary objective of soil site suitability evaluation is to predict the potential and limitation of land for crop production. It is essential to select crops for cultivation according to the soil suitability, so that maximum profit may be achieved while maintaining the ecological sustainability. The importance of soil- site suitability evaluation has grown multifold considering the continuous depletion of soil as a resource under conventional agricultural practice. Under IBM-IORF Sustainability Project at Nadia district, West Bengal, India, soil site suitability of 12 major vegetable and horticulture crops was undertaken to assess whether the presently grown crops are appropriate for the area, and to ensure that the land use plan adopted by the farmers provides better economic returns and livelihood sustenance, under the existential climate change impact. Percent area under highly to moderate suitable for different crops were as follows: Paddy (34 % area), Potato (23 % area), Tomato (39 % area), Bean (40 % area), Chilli (100 % area), Carrot (40 % area), Green peas (40 % area), Onion (37 % area), Cabbage (100 % area), Banana (34 % area), Guava (18 % area) and Papaya (20 % area). Evaluation revealed that soil fertility formed the major bottleneck towards crop cultivation especially due to the poor microbial dynamics in soil, leading to improper nutrient mineralization and availability in the soil solution. Hence, improvement on this aspect can actually promote the suitability aspect of these soils with respect to the presently cultivated crops.

Keywords: soil site suitability, land use, sustainable agriculture, land suitability sub-classes

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Introduction:

Productivity of a particular crop depends on land resources and the climate of the area. The inherent ability of soils to supply nutrients for crop growth and maintenance of soil physical conditions to optimize crop yields is the most important component of soil fertility that virtually determines the productivity of agricultural system (Jayasree, 2022). So, identification of crop requirements and matching them with the resources available to optimize the productivity in a sustainable manner assumes greater importance as the present level of productivity of most of the crops has either reached the plateau or has started declining. Also, crop response to a specific soil property may vary widely with respect to individual crop type and therefore requires crop-wise soil-site suitability evaluation, to adjudge suitable cropping options for an area (Seal *et al*, 2016, Reza *et al*., 2021). This in turn guides the administrators and policy makers for formulating timely decision for movement of agricultural inputs and prediction of crop production (Naidu *et. al.*, 2006).

Hence, soil - site suitability evaluation is the pre-requisite for land use planning (Sys *et. al*., 1993), besides this evaluation also determines the potentialities of soils for alternative uses. Also as soil-site suitability evaluation clearly indicates the nature of constraints that hamper optimal production, scope remains for taking up proper reclamation and management of natural resources within the selected land use framework (Varheye, 1993). Thus study of soil- site suitability of major crops was undertaken in the IBM-IORF sustainability Project (Phase–II), to assess whether the presently grown crops are appropriate for the area, and to ensure that the land use plan adopted by the farmers provide better economic returns and in maintaining their livelihood fighting every moment against the adverse effect of climate change.

Materials and Methods:

Study Area: The area belongs to hot, moist sub-humid ecological sub region (15.1) (Sehgal, 1992). The climate of the study area is characterized by oppressively hot summer, high humidity and high rainfall during the monsoon. Winter starts from the middle of November which continues up to the end of February (Bera *et. al.*, 2021). As per the last 12 years climatic data base, it received about 1962 mm annual rainfall with highest rainfall (475.7 mm) in the month of July. The maximum rainfall i.e. 1800 mm is received during May to October which is about 92% of annual rainfall.

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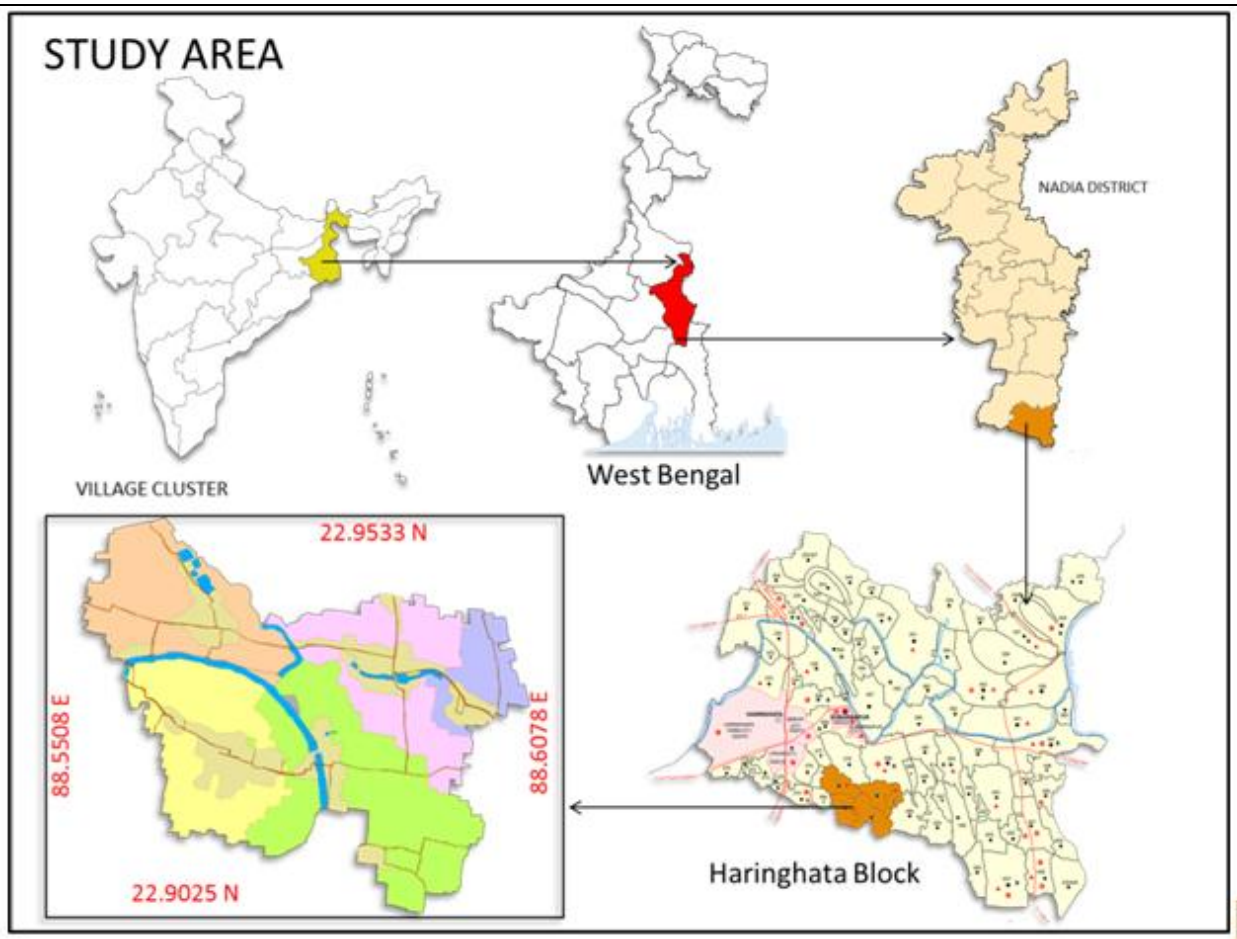

Figure: 1. Study area under IBM-IORF Sustainability Project (2021 – 24)

In terms of physiography, the study area belongs to riverine delta zone and is formed by the materials carried by the Ganga. The area was basically under Meander flood plain. According to Soil Survey Staff (1992) the soils of the study area was very deep, imperfectly drained fine loamy soils occurring on level to nearly level meander plain with loamy surface and moderate flooding associated with very deep, moderately well drained fine silty soils. Fine loamy Fluventic Ustochrepts and fine silty Typic Ustifluvents are the major soils in association (Bera *et. al.*, 2021)

Study of Soil- site suitability of major crops were taken was undertaken in the IBM-IORF sustainability Project (Phase–II) at a cluster of villages viz Satyapole, Bhabanipore, Panchkahaniya, Bansbona and Dhopagachi under Haringhata Block, Nadia District, West Bengal, India. Soil site suitability evaluation was carried out following the criteria outlined by FAO (1976), Sys *et. al.*, (1993) and Naidu *et al.* (2006). The FAO framework involves formulation of climatic and soil-site criteria to meet the requirement of crops and rating of these parameters for highly suitable (S1), moderately suitable (S2), marginally suitable (S3) and unsuitable (N) classes. These were matched with existing land qualities to arrive at a specific suitability class.

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Soil-site suitability of major crops viz., wet season paddy (*Oryza sativa*), potato (*Solanum tuberosum*), cabbage (*Brassica oleracea* var. capitata), chilli (*Capsicum annuum* L.), tomato (*Solanum lycopersicum*), carrot (*Daucus carota* subsp. *sativus*), beans (*Phaseolus vulgaris* L.), onion (*Allium cepa*), green peas (*Pisum sativum*), banana (*Musa sp.*), guava (*Psidium guajava* L.) and papaya (*Carica papaya*) were evaluated in the study area on a 10 ha grid basis. The potential land suitability sub-classes were also determined after considering the improvement measures to correct these limitations (Sys *et. al*.. 1991). The following Subclasses have been defined as : climate limitation (c), topography limitation (t), wetness limitation (w), salinity limitation (n), soil fertility limitation (f) and physical soil limitation (influencing soil/water relationship (s).

Pic 1 : IBm-IORF Sustainability Project towards Net Zero Clean Food production.

Result and Discussion:

Soil- site Suitability Evaluation of Paddy:

In West Bengal agrarian scenario, cropping pattern is dominated by paddy (Rahim *et. al*., 2011). Rice is one of the major crops of this state, and it contributes highest proportion to the rice production of India (about 14 %). Paddy (*Oryza sativa*) covered almost 55.63 per cent of the total cropped area of the state (Das and Kumar, 2018) and wet Season Paddy production in 2020-21 crop year was recorded about 13.3 million ton.

In the study area during the monsoon season wetland paddy is cultivated in almost all the area under lowland and midland and about

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40 % area of upland. As per the soil site suitability study about 62 % area is marginally suitable (S3) for this crop followed by moderate suitability (S2) in about 36 % area while only 2 percent area is under highly suitable (S1) category. However the major limitation was fertility or more precisely soil organic carbon and with correction of this single factor, more than 98 % area can be brought under highly (S1) to moderately (S2) suitable category.

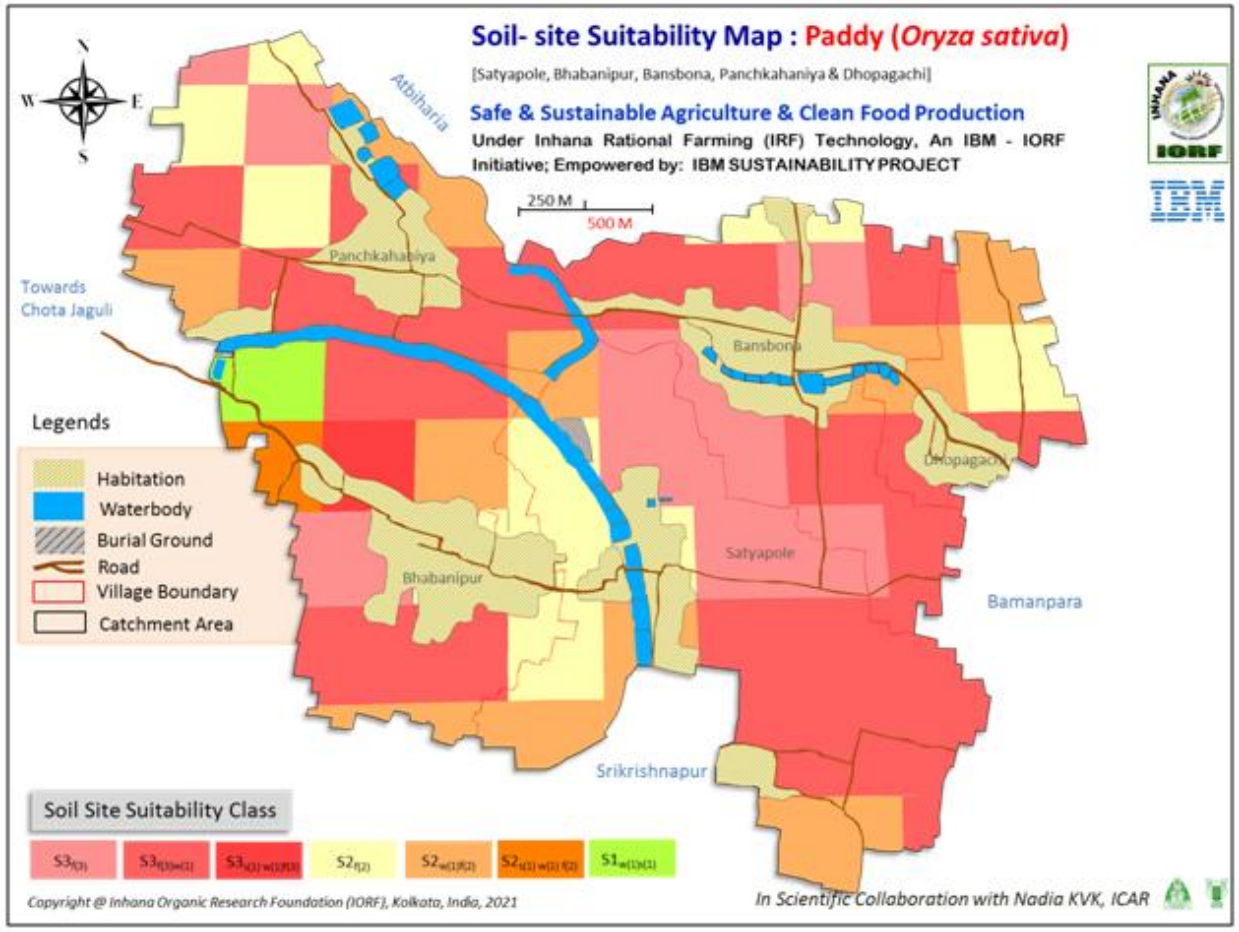

Figure: 2. Soil Site suitability of rainfed paddy in the project area at Nadia, West Bengal, India

Soil- site Suitability Evaluation of Potato

Potato (*Solanum tuberosum* L.) has emerged as the fourth most important food crop in India after rice, wheat and maize (Ojha and Saha, 2014); sharing 20.32 million ha area with an average production of 46.61 million metric tons. In West Bengal, potato is the most popular crop after paddy due to its high production and high return potential. Area under potato in West Bengal is 4.2 lakh hectares and production is 127 lakh tonnes. It is the second largest potato producing state in the country after Uttar Pradesh.

In the study area, potato is one of the important cash crops and a significant area is sown with potato every year. As per the soil- site suitability study about 77 % area was marginally suitable (S3) for this crop

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followed by about 17 % area under moderately suitable (S2) category and only 6 percent area under highly suitable (S1) category. However with correction of soil fertility, about 34% areas can be upgraded to the highly suitable (S1) category while about 66 % area can be brought under moderately suitable (S2) class.

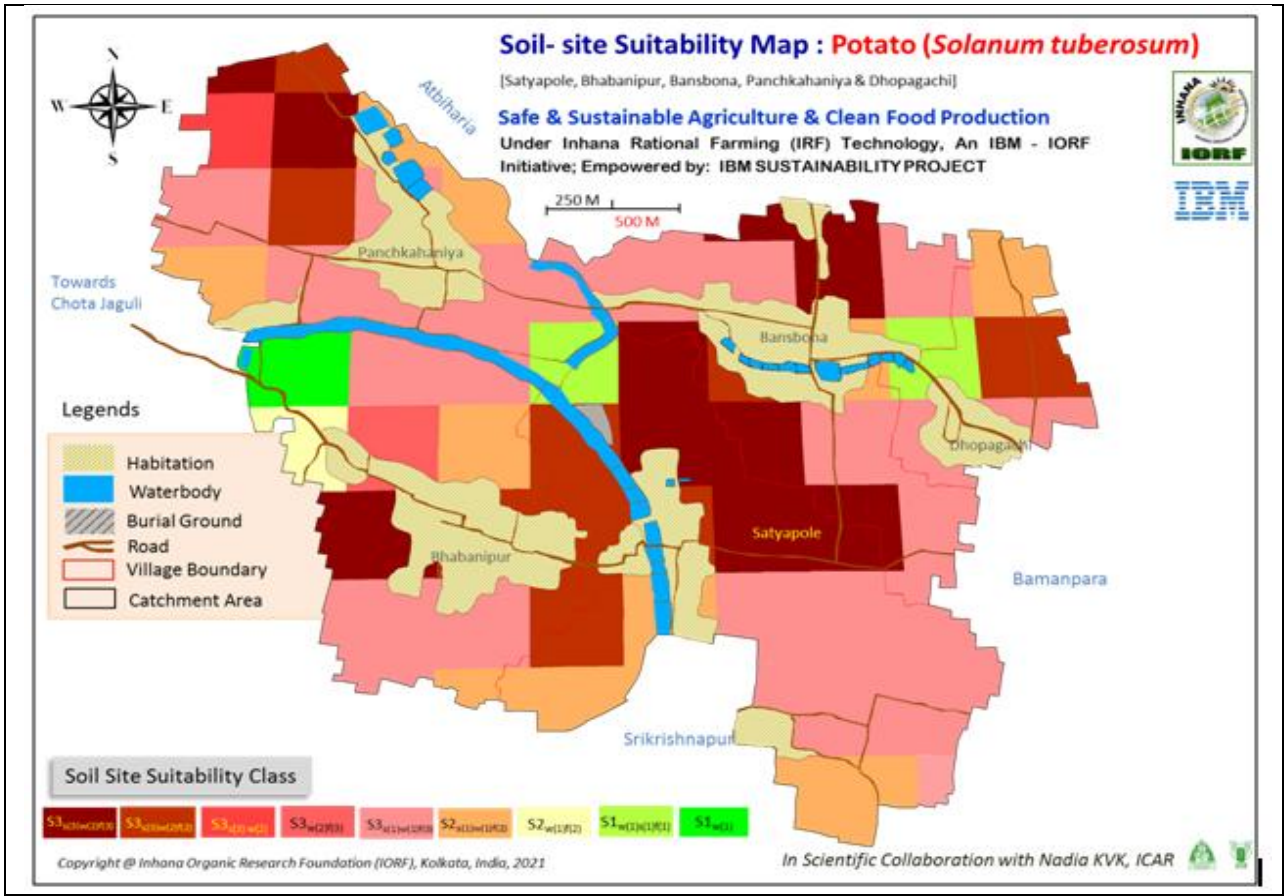

Figure: 3. Soil Site suitability of potato in the project area at Nadia, West Bengal, India

Soil- site Suitability Evaluation of Tomato

Tomato (*Solanum lycopersicum*) is a day neutral plant and can be grown throughout the year depending on the climate. Tomato can be grown in almost all types of soils. However, it cannot withstand water logging. Hence well drained sandy loam soil rich in organic matter is preferred. In India, it is grown in an area of 7.89 lakh hectares with production of 197.59 lakh tonnes. West Bengal occupies an area of 0.57 lakh hectare with production of 12.65 lakh tonnes and productivity of 22.01 t/ha, respectively.

In the study area, tomato cultivation is primarily done in the winter season. As per the soil- site suitability study about 61 % area is marginally suitable (S3) followed by about 33 % area under moderately suitable (S2) category and only 6 percent area under highly suitable (S1) category. Correction of soil fertility, can promote about 67 % areas to the highly suitable (S1) category and 33 % area under moderately suitable (S2) category.

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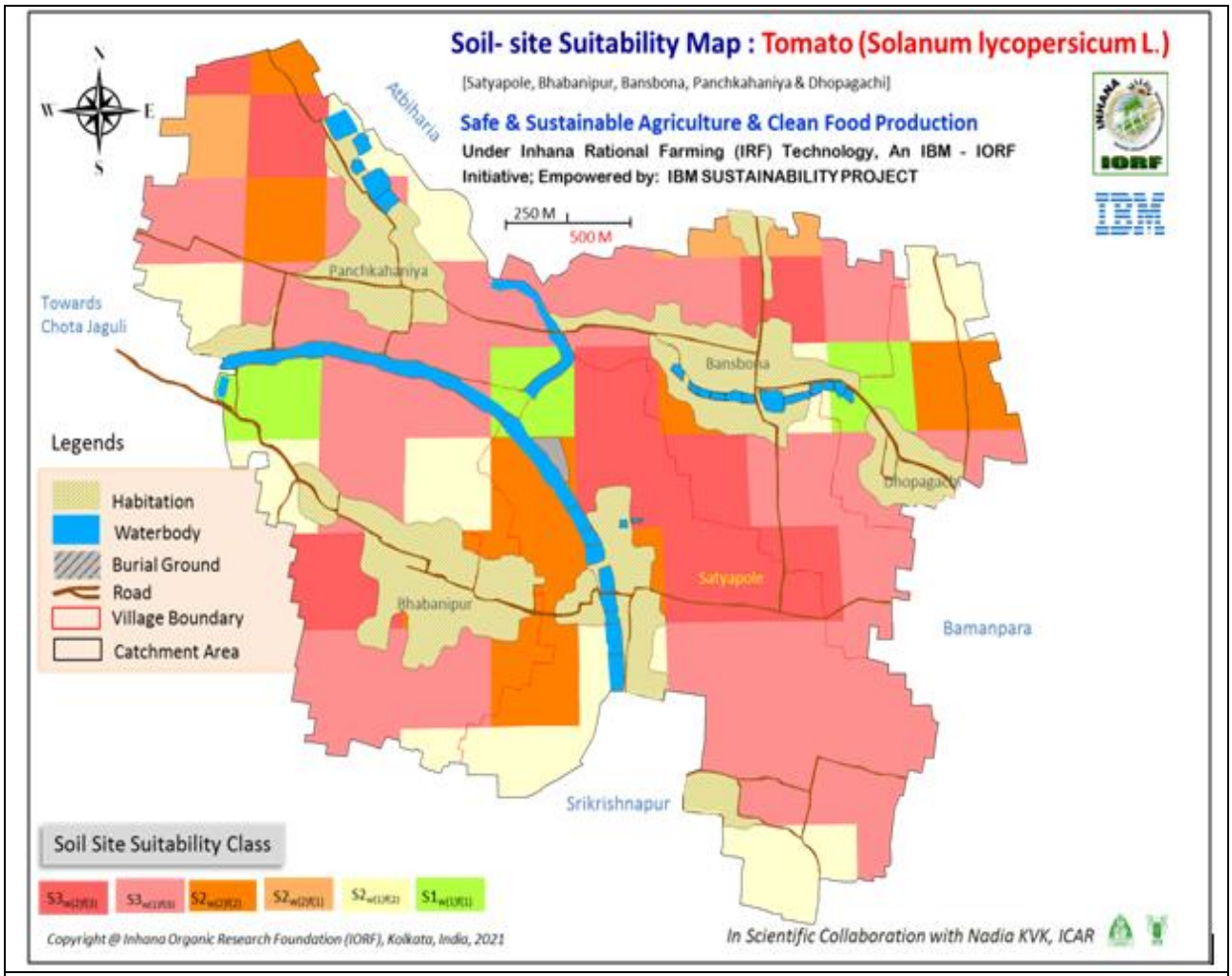

Figure: 4. Soil Site suitability of tomato in the project area at Nadia, West Bengal, India

Soil- site Suitability Evaluation of Bean

Bean (*Phaseolus vulgaris* L.) is an important grain legume for food and cash of the smallholder farmers worldwide. It is considered as a nutritious vegetable as it contains high amount of vegetable proteins, besides carbohydrates and vitamins. In bean production West Bengal is in 7th position and produced about 142 thousand tones in the cropping season 2021-22, contributing about 5.6 % of India's total bean production. Beans grow well in nutrition-rich soil with good drainage. Sandy and silty loamy soils are best for Green Beans, although they can grow in almost any soil variety other than heavy soil.

In the study area basically 3 types of bean i.e. French Bean, Yard long Bean and Broad beans are cultivated singly or as a mixed crop in winter season. But as per the soil site suitability study about 60 % of the project area is only marginally suitable (S3) and the rest 40 % area comes under moderately suitable (S2) category. However with correction of soil fertility, about 63 % area can be upgraded to the highly suitable (S1) category followed by moderate suitability (S2) in the rest 37 % area.

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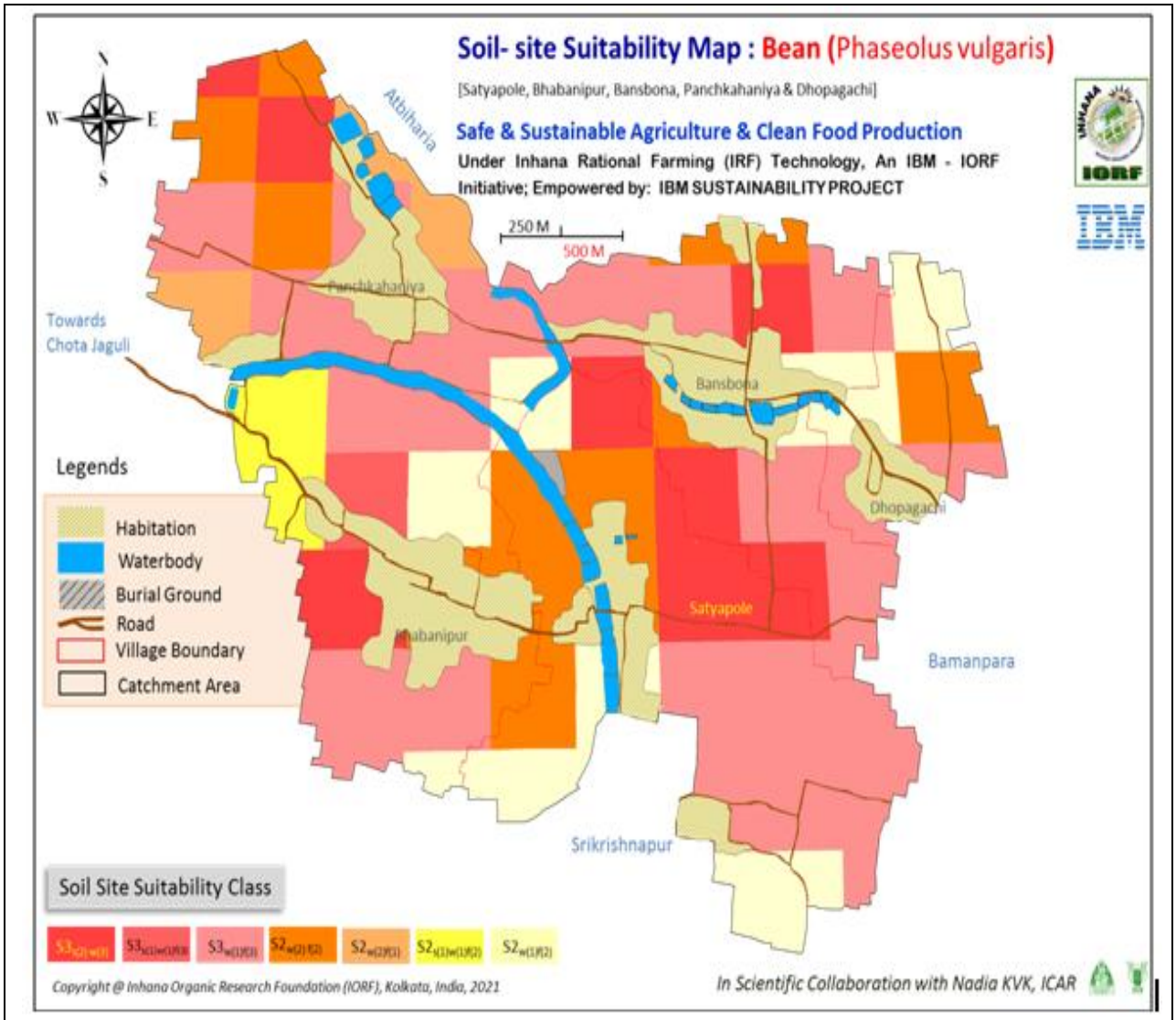

Figure: 5. Soil Site suitability of beans in the project area at Nadia, West Bengal, India

Soil- site Suitability Evaluation of Chilli

Chilli belongs to the genus *Capsicum* under *Solanaceae* family. In India, Andhra Pradesh is the leading state in Chilli production followed by Karnataka, West Bengal and Odisha. In Chilli production, West Bengal is in 16th position and produced about 8.23 thousand tonnes in the cropping season 2021 -22, contributing about 0.44 % of India's total production where as Andhra Pradesh was highest with 700 thousand tonnes and 37 % total production share.

Chilli can be grown in all type of soils, but the sandy - loam, clay loam and loamy soils with pH of 5.5 to 7.0 are best suited for chilli. The soil must be well drained and well aerated. Acidic soils are not suitable for chilli cultivation. As per soil- site suitability study about 77 % of the project area is moderately suitable (S2) while the rest 33 % area is under highly suitable (S1) category. Moreover, with correction of soil fertility, about 65 % area can be brought under the highly suitable (S1) category.

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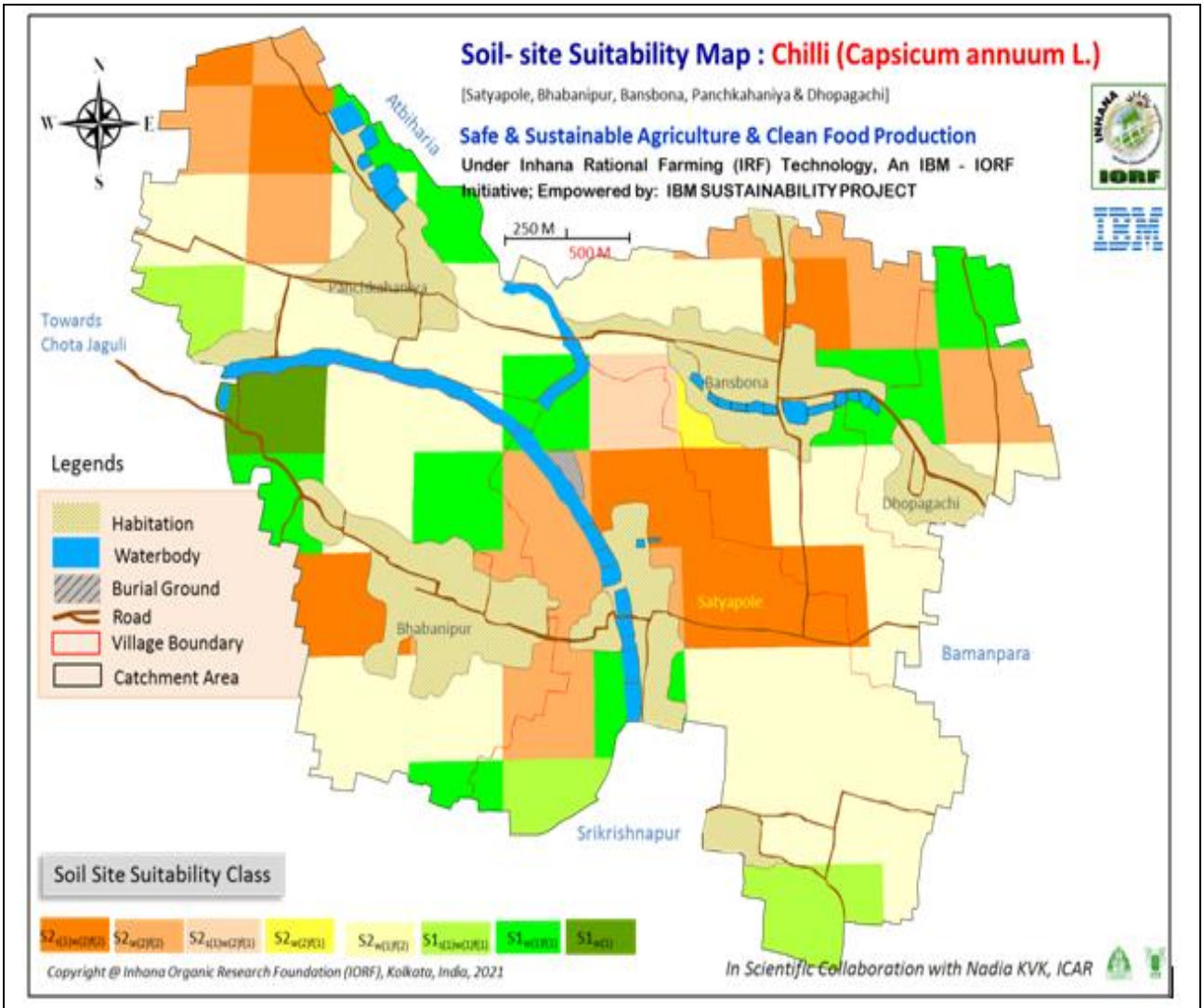

Figure: 6. Soil Site suitability of chilli in the project area at Nadia, West Bengal, India

Soil- site Suitability Evaluation of Carrot

In India, carrot (*Daucus carota*) is grown across the country. In terms of utility, it is an important root vegetable crop. Haryana is the leading producer, followed by West Bengal, Andhra Pradesh, Punjab, Bihar, Tamil Nadu, Karnataka and Assam. In the crop year 2021-22, West Bengal produced about 235 thousand tones of carrot, contributing about 12.32 % of total carrot production in India. The crop needs deep loose loamy soil. It requires a pH ranging from 6.0 to 7.0 for higher production.

In the study area, the farmers grow carrot mainly in the upland in the winter season. As per the soil- site suitability study about 60 % area is marginally suitable (S3) followed by moderately suitable (S2) in about 36 % area, while only 4 percent area is highly suitable (S1) for this crop. Soil fertility again forms the limiting factor here, and with correction about 67 % of the project area can be promoted to the highly suitable (S1) category, with moderate suitability in the rest 33 % area.

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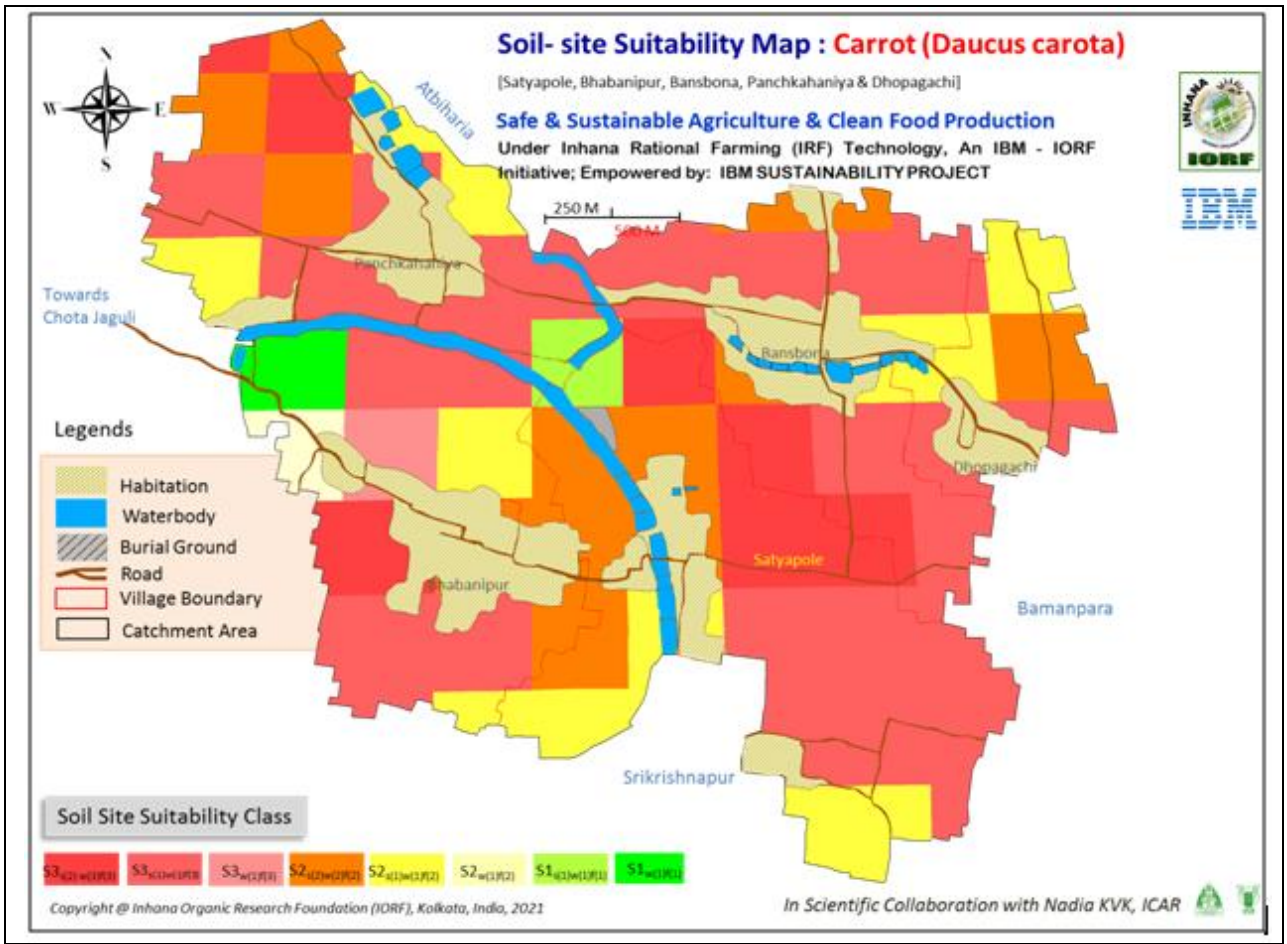

Figure: 6. Soil Site suitability of carrot in the project area at Nadia, West Bengal, India

Soil- site Suitability Evaluation of Green Peas:

Pea (*Pisum sativum* L.) is one of the world's oldest vegetable crops and belongs to the *Leguminosae* family. It is cultivated for its tender and immature seeds for use as vegetable and mature dry seeds for use as a pulse. Peas are a source of vitamins and minerals namely magnesium, thiamine, phosphorus etc. Pea is cultivated all around the world and in India, it can be found in the state of Himachal Pradesh, Madhya Pradesh, Rajasthan, West Bengal, Orissa and many more. Major pea growing states are Bihar, Haryana, Punjab, H.P., Odisha, and Karnataka. According to the latest information, in the year 2021-22, total 6076 thousand tonnes of peas was produced in India in about 582 thousand ha area. West Bengal is in 6th position with about 144 thousand ton productions and about 2.7 % production share.

Peas can be cultivated in a variety of soil types. However well drained, loose, friable and heavy soils with a pH range of 6.0-7.5 are considered as ideal. Light soils are preferred for cultivating early cultivars. Soils rich in organic matter promote excessive vegetative growth and poor pod development. As per the soil-site suitability study about 60 % of the project area is only marginally suitable (S3) for this crop followed by moderately suitable (S2) in about 36 % area and only 4 percent area is

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under highly suitable (S1) class. However with correction of soil fertility, about 66 % area can be brought under highly suitable (S1) category and rest 34 % area under moderately suitable (S2) category.

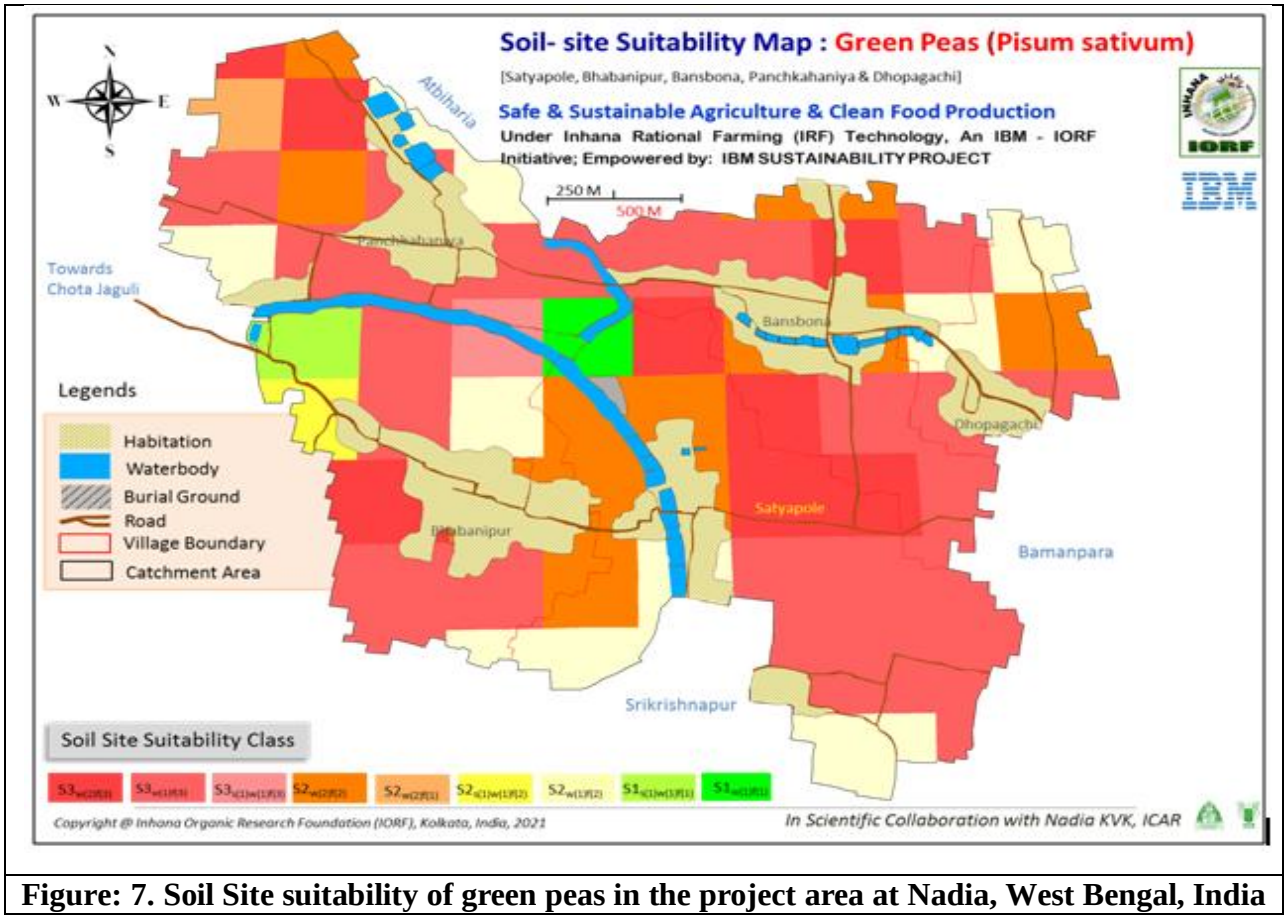

Figure: 7. Soil Site suitability of green peas in the project area at Nadia, West Bengal, India

Soil- site Suitability Evaluation of Onion

Onion (*Allium cepa*) is cultivated by farmers in almost all states of India as both Kharif and Rabi crop synched with geographical location and weather based. In onion production also, West Bengal is in 7th position and produced about 861 thousand tones in the cropping season 2021 -22, contributing about 2.8 % of India's total onion production where as Maharahstra was highest with 13302 thousand tones and 43 % total production share. Onion can be grown in all types of soils such as sandy loam, clay loam, silt loam and heavy soils. However, the best soil for successful onion cultivation is deep, friable Loam and alluvial soils with good drainage, moisture holding capacity and sufficient organic matter. In the study area onions mostly cultivated as a mixed crop.

As per the soil- site suitability study about 63 % of the project area is only marginally suitable (S3), moderately suitable (S2) in about 33 % area while only 4 percent area is under highly suitable (S1) category. But here again, the correction of soil fertility can upgrade about 67 % of the project area to the highly suitable (S1) class, with the rest 33 % area under moderately suitable (S2) category.

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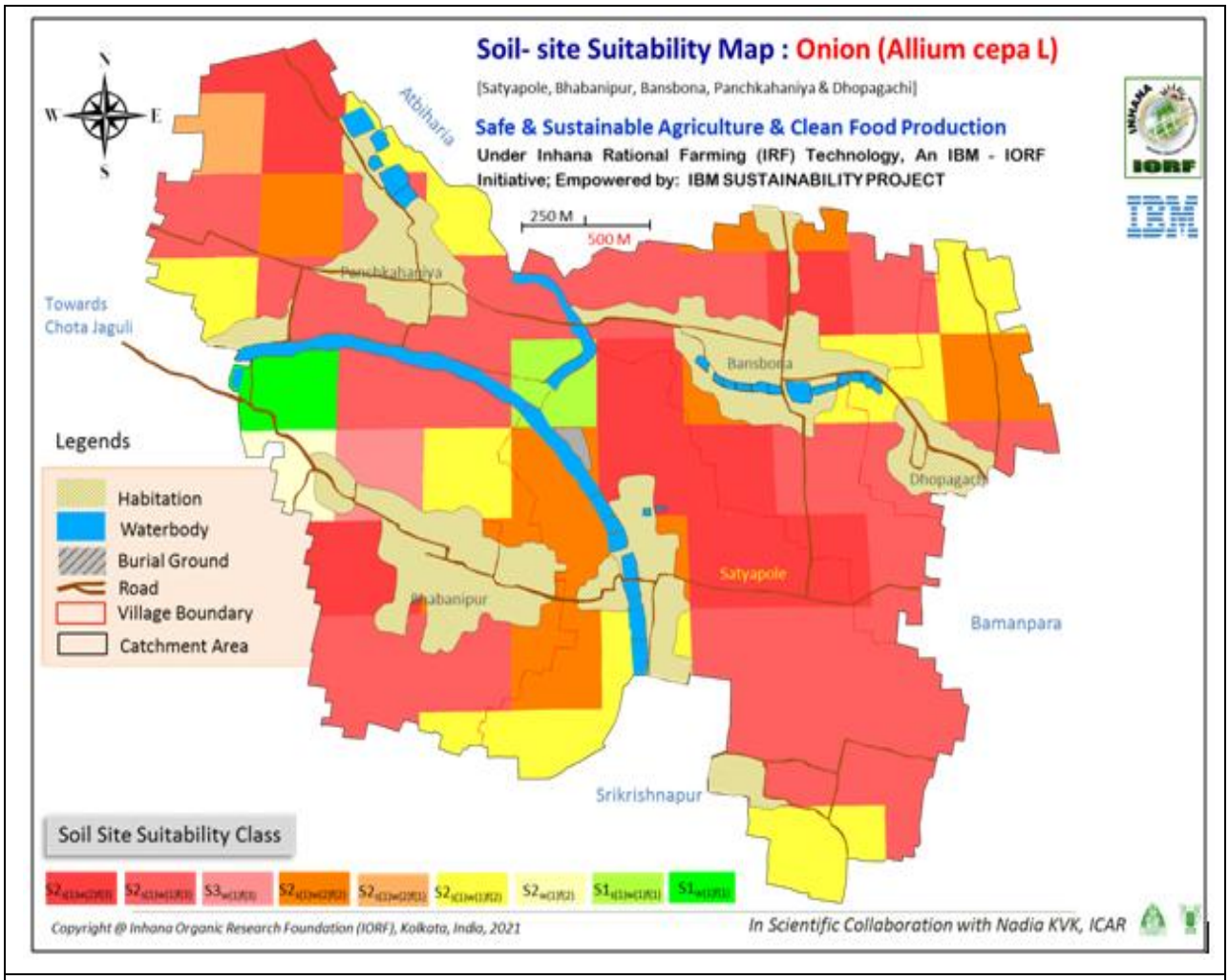

Figure: 7. Soil Site suitability of onion in the project area at Nadia, West Bengal, India

Soil- site Suitability Evaluation of Cabbage

Cabbage (*Brassica oleracea* var. capitata) is one of the most important winter vegetables grown in India and has a high nutritive value. Due to its wide adaptibility, resistance to disease and stress, high yield and good transportation potential, it is cultivated worldwide. The Area and production of cabbage in West Bengal is 0.79 lakh hectare and 22.88 lakh tonnes, respectively and contribute highest (24.4 %) among the states. In the study area, the farmers grow cabbage in significant area in the early winter to pre-summer season.

Well drained loam to sandy loam soil with high organic matter and pH of 6.0-6.5 is ideal for cabbage production. In heavy soils, growth and development of the plants is slow but the developed heads have better keeping quality. Light soils tend to produce early with loose heads. As per the soil- site suitability study, about 79 % of the project belong to the moderately suitable (S2) category, while the rest 21 percent area is highly suitable (S1) for the crop. Correction of soil fertility can promote about 65 % of the area to highly suitable (S1) category.

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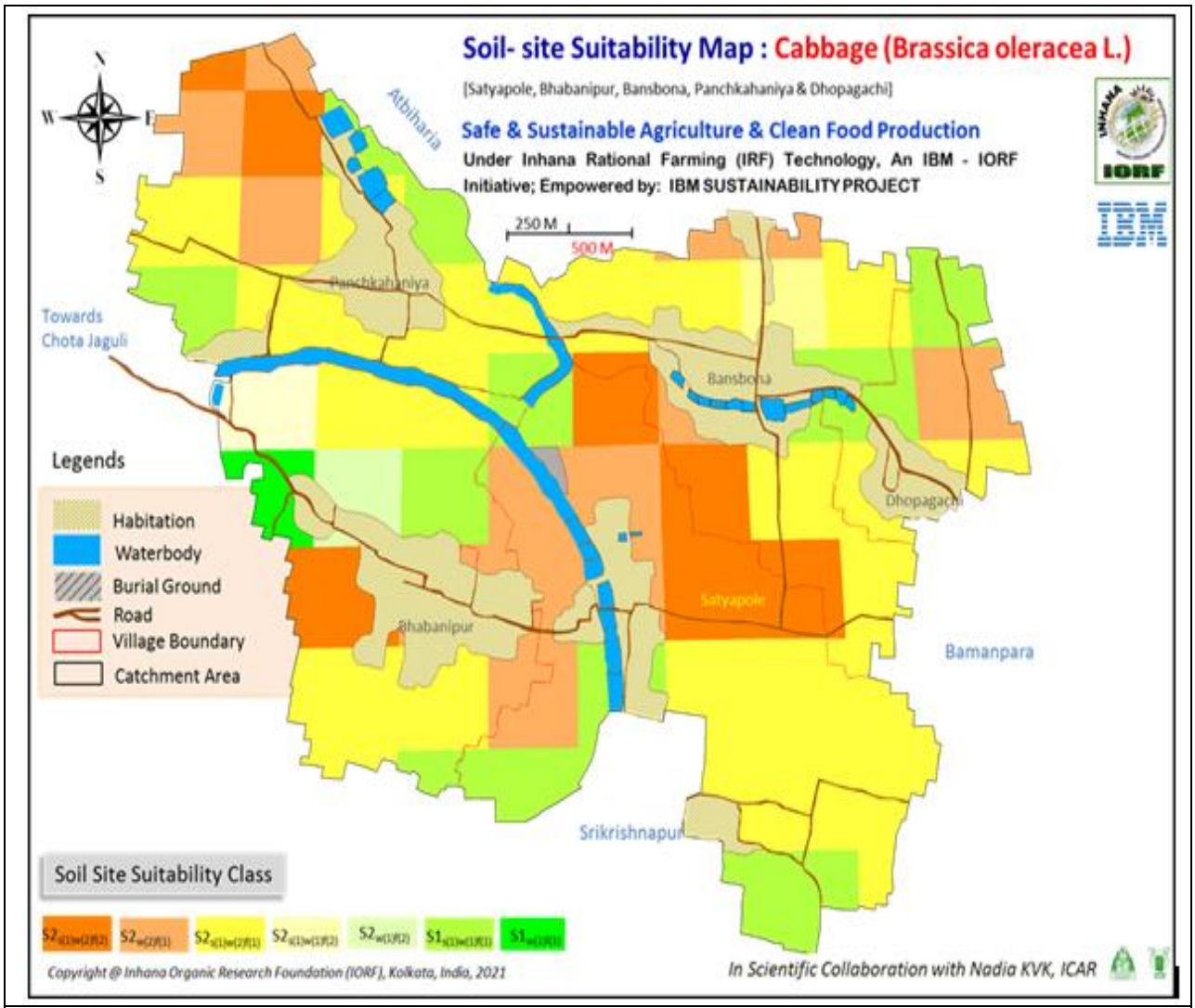

Figure: 8. Soil Site suitability of cabbage in the project area at Nadia, West Bengal, India

Soil- site Suitability Evaluation of Banana

Banana (*Musa* sp.) contributes 37% to the total fruit production in India and occupies 20% of the total cropped area in India. Maharashtra ranks second in respect of area and first in terms of productivity in India. West Bengal ranks 8th and produced 1148 thousand tones in the cropping season 2021-22 contributing about 3.54 % of India's total banana production where as Andhra Pradesh was highest with 5839 thousand tonnes and 18 % of total production share.

The soil suitable for banana should be 0.5-1m in depth, rich, well drained, fertile, moisture retentive, containing plenty of organic matter. The range of pH should be 6.5-7.5. Alluvial and volcanic soils are the best for banana cultivation. As per the soil-site suitability study about 42% area is marginally suitable (S3) followed by moderately suitable (S2) 34% area and most critically 24% under non- suitable (N1) category. However, with correction of soil fertility, about 56 % area can be brought under the highly suitable (S1) category.

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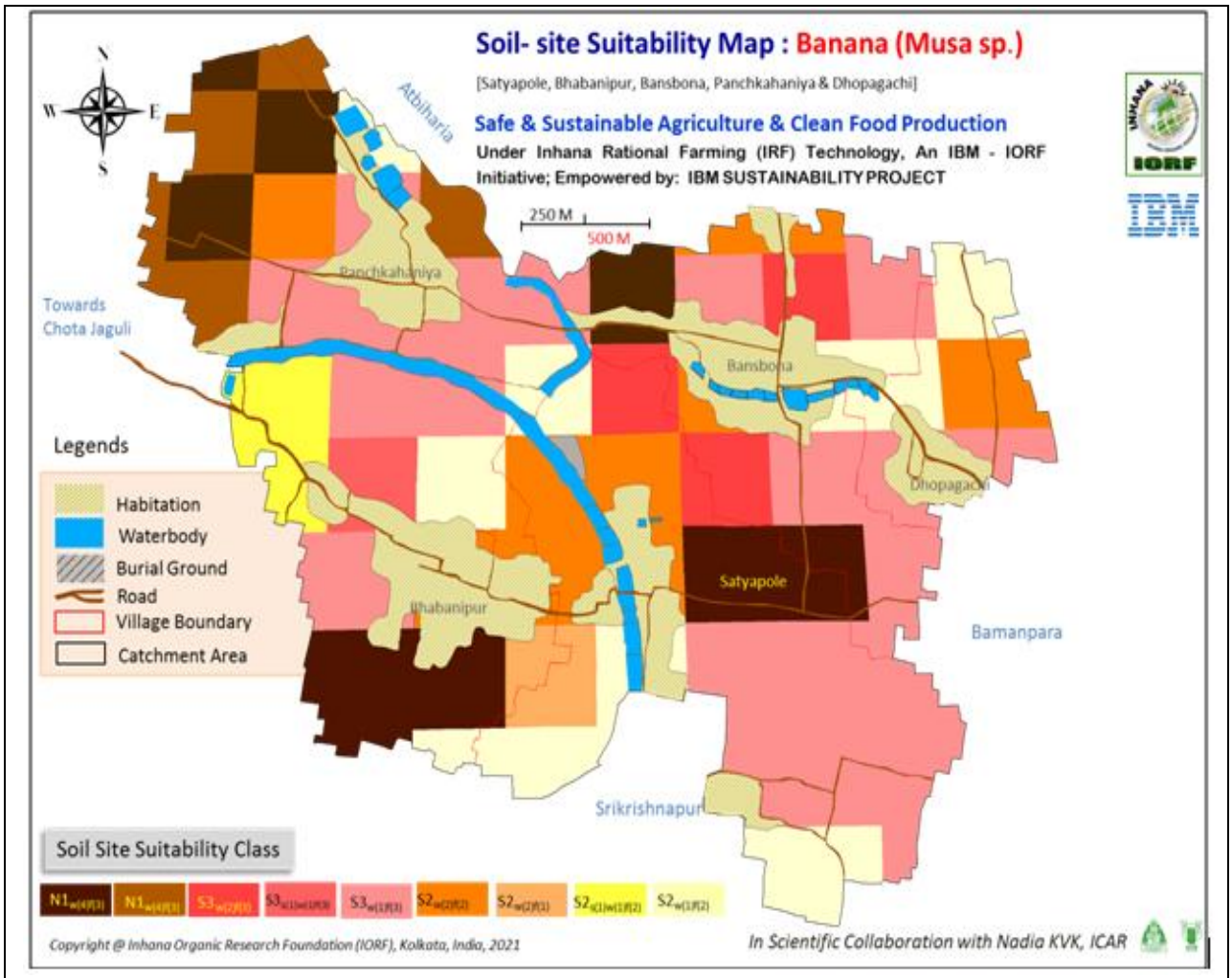

Figure: 9. Soil Site suitability of banana in the project area at Nadia, West Bengal, India

Soil- site Suitability Evaluation of Guava

Guava (*Psidium guajava*) is one of the important commercial fruits in India. It is the fourth most important fruit after mango, banana and citrus. West Bengal ranks 7th and produced 204 thousand tonnes in the cropping season 2021-22 contributing about 4.51 % of India's total guava production where as Uttar Pradesh was highest with 984 thousand tones and 22% total production share. Guava is a hardy plant, which can be grown on wide varieties of soils including shallow, medium black and alkaline soil. However, it grows successfully on well-drained soils with at least 0.5 to 1m in depth.

A soil pH ranging from 6.5 to 8.5 is considered as ideal for higher production but alkaline soils are not suitable for higher fruit production. As per the soil-site suitability study about 58 % areas was marginally suitable (S3) followed by about 18% area under moderately suitable (S2) category while 24% area again under non-suitable (N1) category. However with correction of soil fertility, about 54 % area can be brought under the moderately suitable (S2) category.

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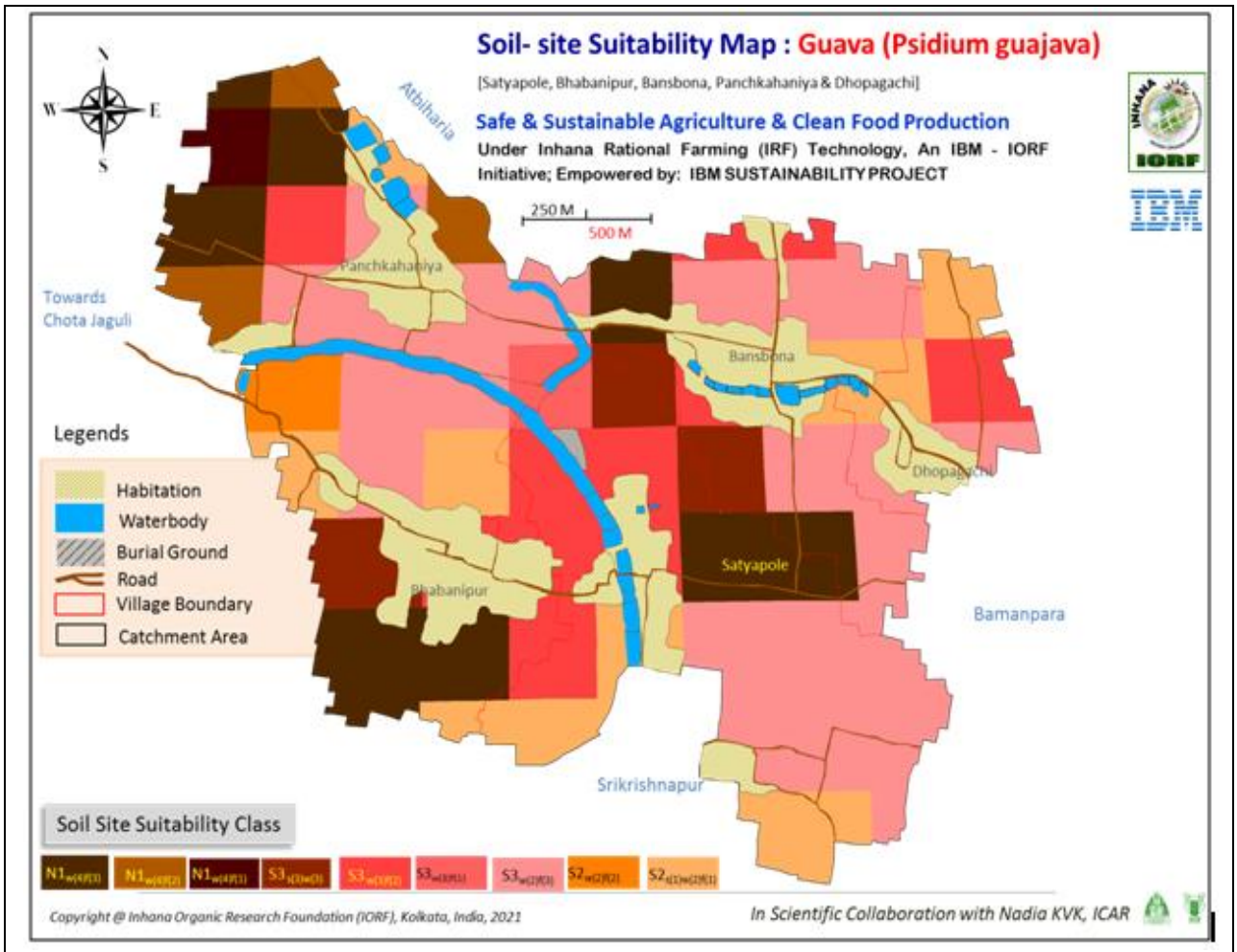

Figure: 9. Soil Site suitability of guava in the project area at Nadia, West Bengal, India

Soil- site Suitability Evaluation of Papaya

India is the largest producer of papaya (about 5.7 million tonnes), contributing 42% of world production from 30% of the global area under papaya (*Carica papaya*) cultivation. The area under papaya cultivation is 1.9% of the total area under fruit cultivation and its production is 6.6% of India's total fruit crops. West Bengal ranked 7th and produced 300 thousand tonnes in the cropping season 2021 -22 contributing about 5.22 % of India's total papaya production where as Andhra Pradesh was highest with 1503 thousand tonnes and 26 % total production share. A high fertile soil with good drainage is most desirable for successful papaya cultivation. The plant grows well in sandy loam soil having pH between 6.5 to 7.0. Papaya grows well in sunny, warm and humid climate.

The plant can be grown upto an elevation of 1000 m above the sea level but can't withstand frost. As per the soil site suitability study about 56 % of the project area is marginally suitable (S3) followed by moderate suitability (S2) in about 20 % area with rest 24 % area under non suitable (N1) category. However, here again correction of soil fertility, can upgrade about 68 % of the project area to the moderately suitable (S2) class.

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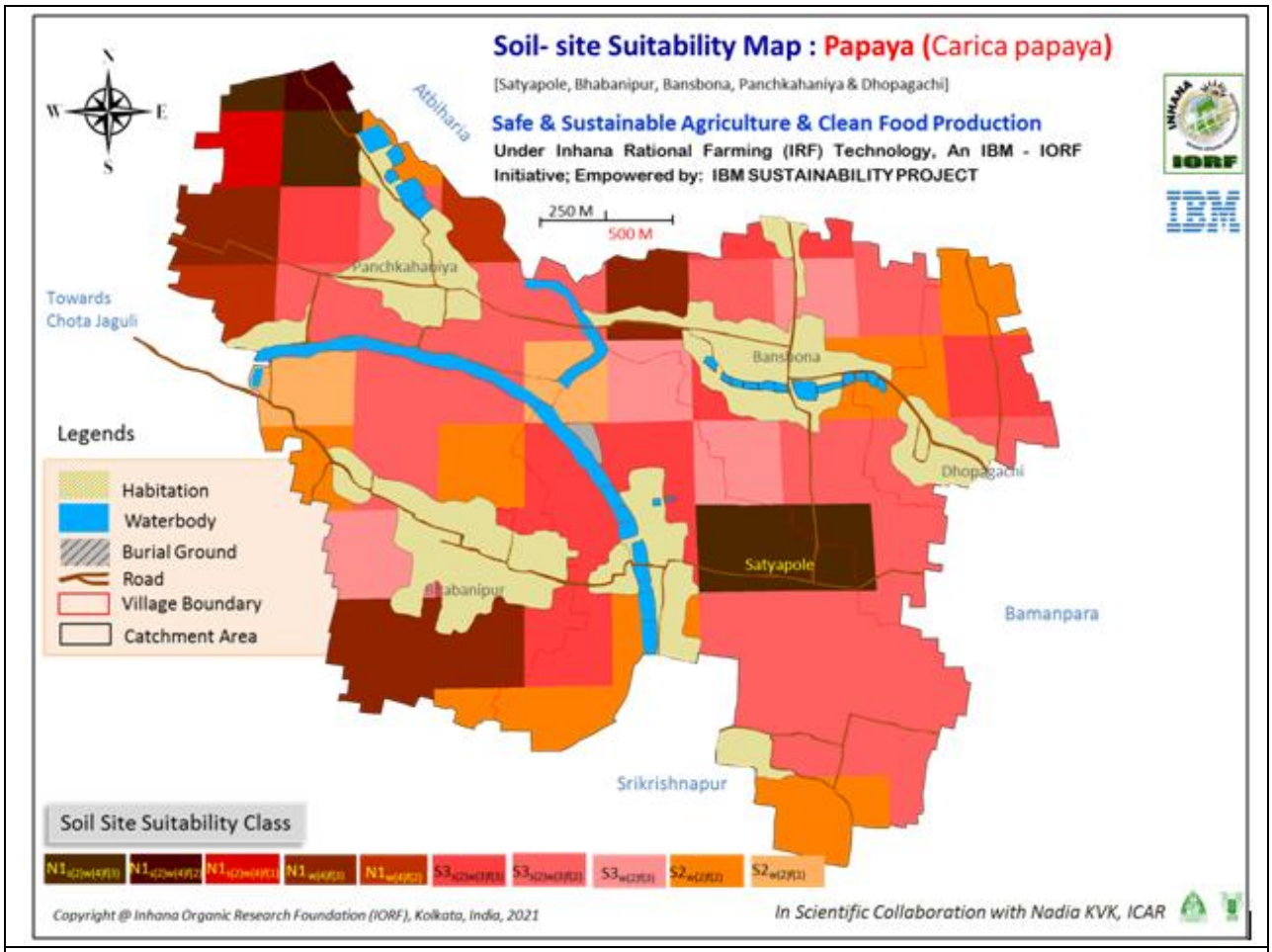

Figure: 10. Soil Site suitability of papaya in the project area at Nadia, West Bengal, India

Conclusion:

Soil site suitability of any crop is important in terms of land use planning and developing farmers' livelihood program. Soil site suitability of the major crops grown in the study area revealed that with correction of fertility parameter, crop productivity potential of most of the crops can be improved which requires a nature based sustainable management program.

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