Mapping the Nutrient Status of Odisha's Soils

Sreenath Dixit, Prasanta Kumar Mishra, M Muthukumar,
K Mahadeva Reddy, Arabinda Kumar Padhee and Antaryami Mishra

ICRISAT
INTERNATIONAL CROPS RESEARCH
INSTITUTE FOR THE SEMI-ARID TROPICS

Citation: Dixit S, Mishra PK, Muthukumar M, Reddy KM, Padhee AK and Mishra A (Eds.). 2020. Mapping the nutrient status of Odisha's soils. International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and Department of Agriculture, Government of Odisha. 342 pp.

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MESSAGE

I am glad to learn that ICRISAT, in collaboration with the Directorate of Agriculture, Government of Odisha is bringing out a volume on *Mapping the nutrient status of Odisha's soils* which encapsulates the nutrient status of different types of soils across all regions of the State.

Soil quality and health are keys to sustainable agriculture, which in turn, is crucial to food and nutrition security. The inherent soil characteristics, its material and texture have also a direct bearing on water quality in a region. As such, knowing the composition and micronutrients of the soil is vital both for enhancing 'agricultural productivity' and modifying water 'quality management'.

It is quite appropriate that the information contained in the volume is based on the analysis of soil samples collected from all 30 districts of the State. I am sure, the volume will serve as a hand book for the agricultural scientists, officers engaged with farmers at the cutting edge level, and all those aiming at agricultural transformation in the State.

I compliment the efforts of ICRISAT, its authors and editors, namely S Dixit, PK Mishra, M Muthukumar, KM Reddy, AK Padhee, A Mishra and all their associates who have undertaken a systematic scientific endeavor to bring out this useful volume.

(Asit Tripathy)

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Letter No. 15139/A&FE,
Dated 30-9-2020

Foreword

More than 70% of the population of Odisha in India is dependent on agriculture and allied activities for their livelihood. The state is endowed with rich natural resources and biodiversity. However, growth in the agricultural sector has been sluggish due to severe degradation of natural resources, especially soils. Soil health plays a crucial role in reaping the benefits of improved agricultural technologies. The acidic nature of the soils have led to widespread deficiencies in nutrients, especially micronutrients, limiting crop yields and posing a threat to food security in the state.

Testing soils and estimating their nutrient status are critical to ensure increased crop productivity and to reduce the cost of cultivation through judicious and balanced use of nutrients. The Government of Odisha (GoO) made concerted efforts to estimate the nutrient status of soils by setting up soil testing laboratories across the state. However, there is a lacuna in the estimation of secondary and micronutrients and in developing tools to interpret the soil testing data, hindering efforts towards planning for and implementing steps to improve soil status.

Odisha Bhoochetana is a novel and flagship programme initiated jointly by GoO and ICRISAT during 2018 to demonstrate and upscale technologies to enhance crop productivity through the adoption of soil test-based nutrient application. Under this initiative, an accurate analysis of soil samples across 30 districts in the state to estimate primary, secondary, and micronutrient was done status resulting in a recommendation for their management for various crops.

It gives me immense pleasure that ICRISAT in association with DoA has brought out this publication titled *Mapping the nutrient status of Odisha's soils*. I am sure it will be of great use to policymakers, administrators, and block-level officials as a ready reckoner while devising plans and making decisions on the judicious use of nutrient management practices across various agricultural production systems that can augment crop productivity and reduce the cost of cultivation.

I congratulate the ICRISAT and DoA teams for their efforts in bringing out this publication.

Saurabh Garg
30/9/2020

Dr Saurabh Garg
Principal Secretary- Agriculture
Government of Odisha

Preface

The economy of the state of Odisha is agrarian. The state is blessed with abundant natural resources to support agriculture and allied activities. However, agriculture has seen a decelerating growth rate in the recent past. Overexploitation of natural resources, especially land; the prevalence of acidic soils that limit the uptake of nutrients and faulty management practices have led to reduced crop productivity and slowed down growth in agriculture. Widespread deficiencies in secondary and micronutrients are a cause for concern among researchers, policymakers and development departments. A majority of farmers don't have the knowledge of the crucial role micronutrients play in plant nutrition; disseminating this information to them could be a great enabler. Reversing this trend calls for soil testing to go hand in hand with the adoption and implementation of good practices that can achieve desired results. This requires a multipronged strategy that encompasses mapping soils to ascertain their nutrient status, demonstrating the benefits of the balanced use of soil nutrient application to improve crop yields and making sure quality nutrients are available across the state.

The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Hyderabad, under the aegis of the Department of Agriculture (GoA), GoO, initiated scaling up initiatives of proven technologies such as improved cultivars and nutrient and pest management practices as part of a project titled "Enhancing Agricultural Productivity and Rural Livelihoods through Scaling-up of Science-led Development in Odisha: Bhoochetana" under the Rashtriya Krishi Vikas Yojana (RKVY) during 2018-19. The analysis of 40,265 geo-referenced soil samples from across 30 districts and estimating their nutrient status was accomplished using state-of-the-art equipment. In order to create extrapolation domains, a decision support tool to map the nutrient status of soils was created using GIS and web-based tools. Though there were some initial hiccups in the collection and transportation of soil samples, this herculean task that involved engaging, guiding, coordinating and monitoring field level teams across 30 districts was accomplished successfully.

Mapping the nutrient status of Odisha's soils was brought out by ICRISAT and DoA with a view to bringing this knowledge on soil status out in the public domain and for the benefit of farm functionaries and the larger farming community. The publication begins with a narration of how the idea of Bhoochetana (bringing vitality or life to soils) germinated, going on to the evolving of soil testing and nutrient management strategies, soil sampling and analysis, the development of soil test-based fertilizer recommendations, management of acidic soils, the development of more than 250 detailed soil nutrient maps and an online application to view this information.

This publication will be of great use to policymakers, administrators, block-level officials, extension workers and farmers as a ready reckoner to devise and implement nutrient application practices across various agricultural production systems at the block, district and state levels.

Editors

Acknowledgements

This book is one of the outputs of the project "Enhancing Agricultural Productivity and Rural Livelihoods through Scaling-up of Science-led Development in Odisha: Bhoochetana" funded by the Government of Odisha. We thankfully acknowledge the funding support provided by the Government of Odisha for implementing the project across all the districts of the state. We also thank all the district agricultural officers and their staff, field functionaries and farmers for supporting the initiative that enabled soil sample collection, analysis and the preparation of maps which are now part of this book.

Chapter 1

Bhoochetana: Reviving Soils for Agriculture

Girish Chander, Sreenath Dixit and Gajanan Sawargaonkar

The evolution: Earlier attempts & learnings

Insights from an exemplar scaling-up initiative in Karnataka

The *Bhoochetana* program in Karnataka, India, has been one of the initial exemplar attempts at scaling-out best practices in reviving soils on a large scale involving thousands of farmers in the state. The stagnant to declining growth of the agriculture sector in Karnataka between 2000 and 2008 demanded a multi-pronged strategy to revive agriculture. Given the alarming situation, in 2009 the state initiated measures to address soil health through a state-wide, flagship program called *Bhoochetana*. The program was designed to get the state's agriculture back on track by increasing crop productivity and strengthening agriculture-based livelihoods.

Deterioration in soil fertility and the widespread prevalence of nutrient deficiencies, especially of micronutrients, posed a threat to soil health, the productive performance of crops, incomes of millions of smallholder farmers and more importantly, food security of the state (Sahrawat et al. 2007, 2016). Against this backdrop, extensive soil nutrient mapping was initiated to assess the extent of soil degradation. As an entry point activity, large-scale soil sampling was initiated to build a rapport with the farmers, as a prelude to securing their buy-in as partners in the process of restoring soil health. A stratified soil sampling methodology was adopted involving the collection of a proportionate number of samples from all the three toposequences, i.e., upper, middle and lower from 25% of the representative villages in each of the 176 blocks of the state. Further, at each toposequence, samples were collected proportionately from different farm size groups, i.e., small, medium and large. Care was taken to collect an equal number of samples to represent soil colour and texture, cropping system and agronomic management systems practiced by the farmers. More than 100,000 samples collected were analyzed in the state-of-the-art Charles Renard Analytical Laboratory (CRAL) at ICRISAT, Hyderabad.

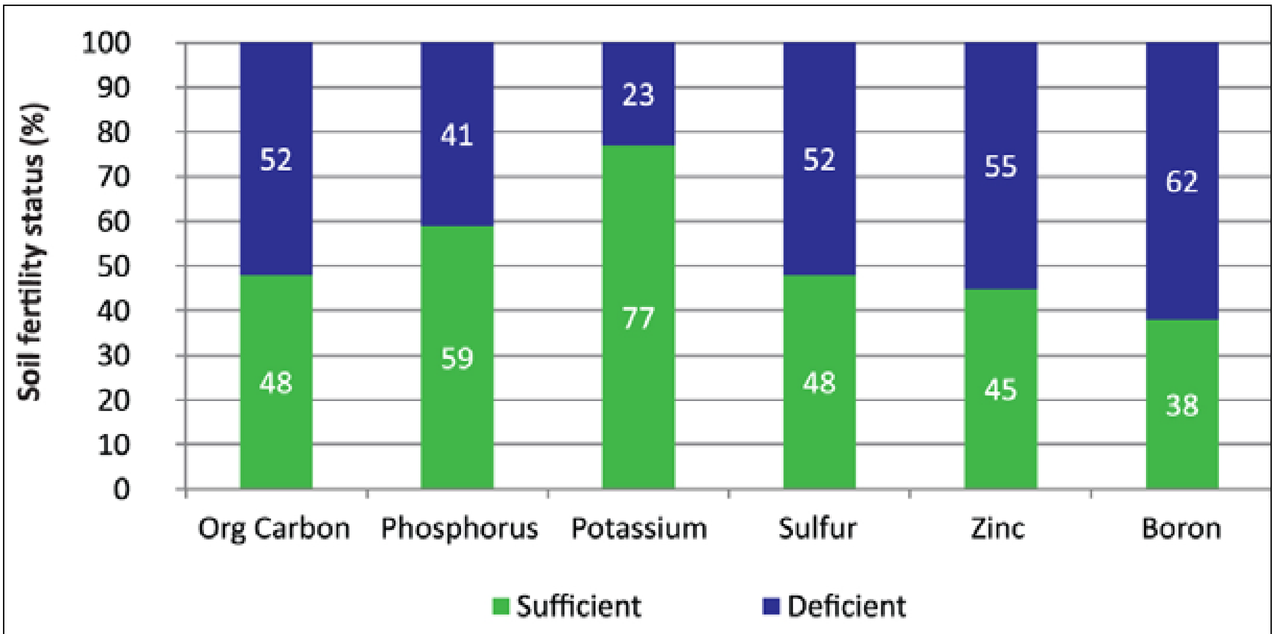

Figure 1.1 Soil fertility status of farmers' fields (2009-2013) in Karnataka, India (Chander et al. 2016).

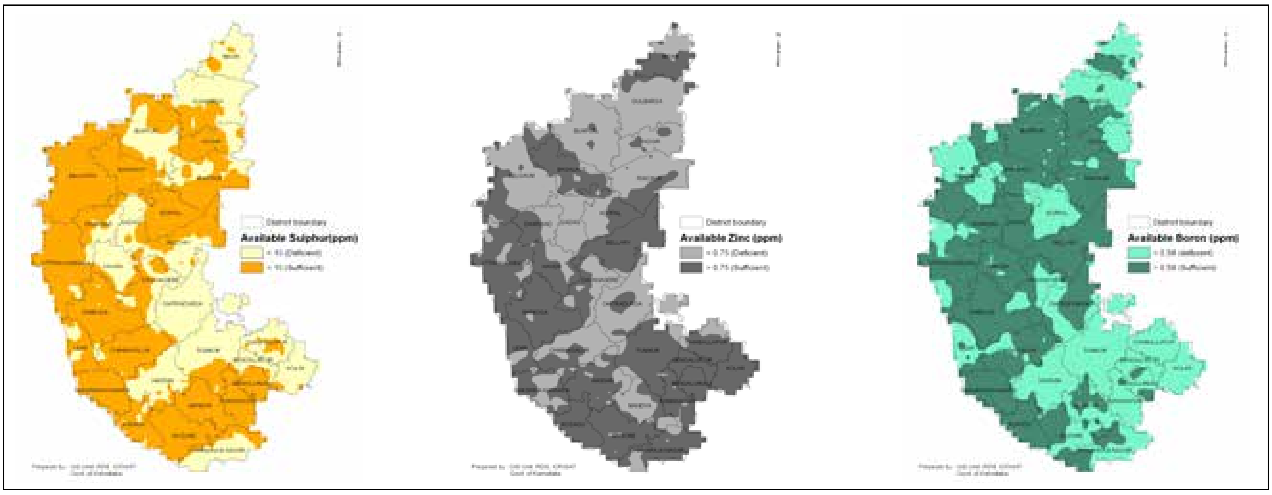

Figure 1.2. Extensive micro- and secondary nutrient deficiencies in Karnataka (Wani et al. 2016).

Results revealed that unabated stripping of nutrients over the years had resulted in severe deterioration in soil health and widespread deficiencies in multiple nutrients. (Wani et al. 2011). Some secondary and micronutrients had been depleted below their critical limits, adversely affecting nutrient and water use efficiencies of soils. While the study revealed widespread deficiencies in zinc (Zn), boron (B), sulfur (S), nitrogen (N) and phosphorus (P), it showed adequate potassium (K) in the soils (Figures 1.1 and 1.2)

This analysis formed the basis for recommending nutrient application at cluster/village/block levels, as opposed to the conventional system of recommending a blanket fertilizer application at the state level. It helped the state make an informed decision on including deficient micro/secondary nutrients in its fertilizer recommendations. At the block level, a full dose of micro/secondary nutrients was suggested if the deficiency was more than 50%, half a dose if less than 50% and no application where there was single digit deficiency. To reinforce the importance of healthy soils and create awareness among the farmers, the program conduced large-scale capacity building programs, set up wall writings, issued soil health cards, developed soil fertility maps, held farmer days, facilitated exposure visits and trained lead farmers. Best bet management practices were scaled out on about 5 million ha by strengthening institutional arrangements, capacity building and timely supply of inputs in the state. Soil test-based nutrient management significantly increased productivity. The incremental benefits varied from 25% to 47% in cereals, 28% to 37% in pulses and 22% to 48% in oilseed crops (Chander et al. 2016). The results also showed that for every rupee spent, there was a benefit of ₹ 3-15 across various regions in the state. This science-led development effort clearly demonstrated the scalability of the initiative, infusing sustainability and resilience into the state's agriculture.

Taking a leaf out of *Rythu Kosam* in Andhra Pradesh to establish sites of learning

Taking a cue from the Rythu Kosam (meaning for the farmer) primary sector project in Andhra Pradesh, state in India, a two-pronged strategy was adopted in Odisha to establish pilot sites of learning. Under Rythu Kosam (2015-2018), pilots were established on 10,000 hectares covering 265 villages across 13 districts and 36 blocks in Andhra Pradesh. The pilot sites served as on-farm field laboratories to test and evaluate technological/institutional/policy innovations and fine-tune the initiatives. In marketing parlance, the pilot areas were test markets for innovations, which were demand driven, impact oriented and having measurable indicators. While these sites served to monitor proven integrated nutrient management technologies with high guaranteed levels of success, they were a testing ground to evaluate and customize on-farm innovations and technology products. State government line departments converged their block action plans with the pilot sites to promote a holistic and systems approach.

The successfully tried and tested soil health mapping in the *Bhoochetana* program and other watershed sites was adopted as an entry point activity to rejuvenate soil resources. The analysis of about 5400 soil

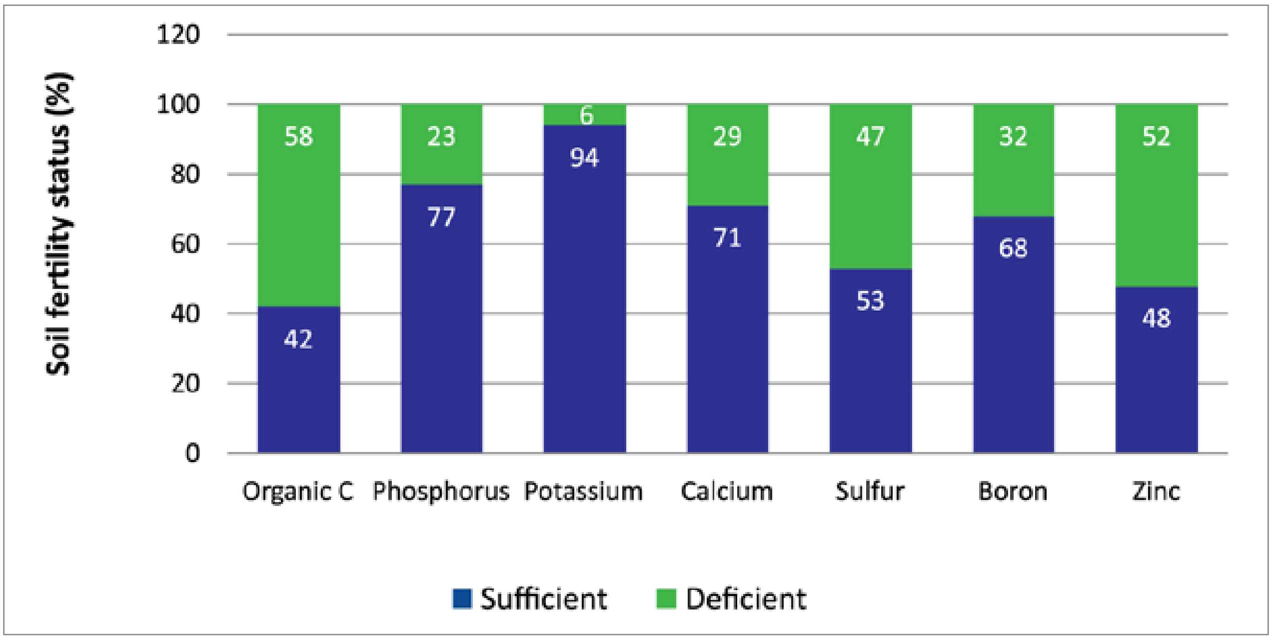

Figure 1.3. Soil fertility status of farmers' fields in pilots across Andhra Pradesh, India (Wani et al. 2018b).

samples collected from pilot sites from April to June in 2015 showed multi-nutrient deficiencies in zinc, boron, sulfur and calcium in addition to lower levels of soil organic carbon, nitrogen and phosphorus (Figure 1.3). This was followed by crop-wise recommendations for primary, secondary and micronutrients that were demonstrated in field trials at the pilot sites. Data from the field trials revealed that the analyses-based application of nutrients gave a yield advantage of 10-40% in cereals, pulses, oilseeds and vegetable crops. These encouraging findings gave a policy direction to the Government of Andhra Pradesh to scale-out soil test-based nutrient application over 1.50 million hectares.

In yet another initiative under this project, easy and quicker methods of converting crop residue into manure were demonstrated, such as the aerobic process of composting, use of crop residue shredders and bio-culture-enabled rapid decomposition of non-fodder biomass. This helped translate a proof of concept into a practical solution that aided building of soil organic carbon *in-situ.* It also served to reduce the cost on chemical fertilizers across all the sites of learning (Chander et al. 2018), while at the same time regulating soil health and improving crop yields. Demonstration of improved crop cultivars at the pilot sites showed a yield advantage of 10-50% compared to farmers' practices. These demonstrations brought home to stakeholders the importance of and benefits from making informed decisions on improving soil health and restoring the agro-ecosystem balance though judicial use of inputs, system intensification/diversification, introduction of best-bet soil-crop-water-livestock technologies, strengthening institutional arrangements and alignment of policies.

Scaling-up in Odisha

Soil health mapping, need-based nutrient management and best practices

The *Bhoochetana* project in Odisha state aims at improving crop productivity and rural livelihoods through science-based natural resource management practices. The specific objectives of the project are to:

- Assess the nutrient status of soils in all the 30 districts;
- Identify the best nutrient, soil, crop and water management options to increase productivity through demonstrations in pilot sites;
- Scale-up best practices in partnership with the Directorate of Agriculture (DoA) and other partners through convergence;

- Build the capacity of DoA staff, consortium partners and farmers to support scaling up of a science-led holistic development strategy;
- Concurrently monitor, evaluate, and document the impacts of the scaling up approach in order to enable mid-course corrections; and
- Upgrade two existing soil analytical laboratories in the state to serve as referral laboratories and run them efficiently with government support.

Soil health mapping was undertaken across 30 districts of Odisha by collecting 40,265 samples using stratified random sampling. This formed the basis of a precise and robust nutrient management strategy for the state (Figure 1.4). It also envisagesd economic and environmental benefits by avoiding the indiscriminate use of major nutrients like N, P and K fertilizers.

Taking into account the large-scale deficiencies in secondary and micronutrients, an expert consultation was organized between scientists of Odisha University of Agriculture and Technology (OUAT), ICAR-National Bureau of Soil Survey and Land Use Planning (ICAR-NBSS&LUP), Department of Agriculture (DoA), Government of Odisha and ICRISAT to devise a strategy in line with the state's nutrient recommendation policy. The consultation came out with the following recommendation:

- Application of 25% more NPK in case of low nutrient status and 25% less NPK when nutrient status is high (Table 1);
- Critical levels of deficiency for S, Zn, B, Cu, Fe and Mn are 10 mg/kg, 0.6 mg/kg, 0.5 mg/kg, 0.2 mg/kg, 4.5 mg/kg and 2 mg/kg, respectively;
- Yearly recommended dosage of boron is 1 kg/ha;
- The recommended dosage of sulfur is 30 kg/ha in cereals (i.e., 200 kg/ha through gypsum), 40 kg/ha in pulses and 45 kg/ha in oilseed crops;
- In the case of zinc, the recommended dosage is 5 kg/ha in paddy, 2.5 kg/ha in pulses and 2.0 kg/ha in oilseeds;

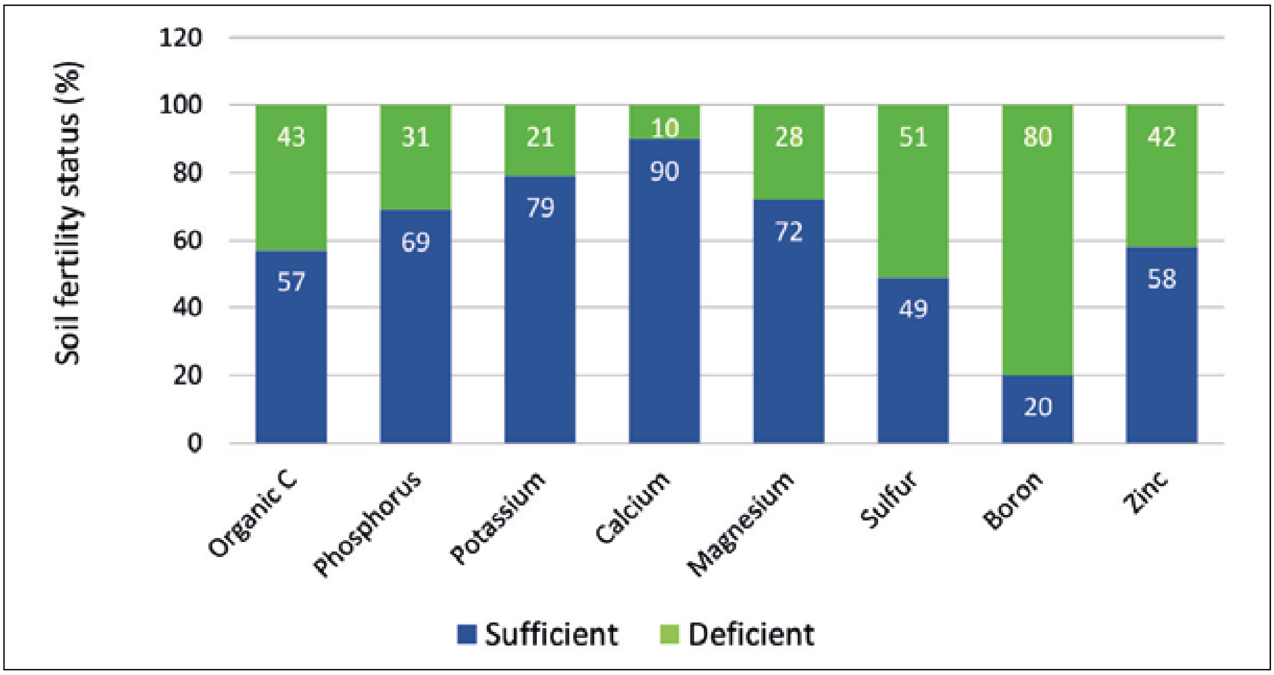

Figure 1.4. Soil fertility status of farmers' fields based on an analysis of 40,265 soil samples collected from across all the districts of Odisha, India.

- Digital soil maps to be the reference for soil fertility and recommendations;
- Large-scale promotion of aerobic composting both at individual and community levels;
- Promote the application of well decomposed poultry manure @ 2.5 t/ha in furrows as a substitute for lime in acid soil management; and
- Promote seed priming with 1% zinc sulphate heptahydrate and 1% KH_2PO_4 in acidic soils.

Table 1.1. Critical limits for low, medium and high levels for N, P and K.

Plant nutrient	Critical level (kg/ha)		
	Low	Medium	High
N	<225	225-560	>560
P	<10	10-25	>25
K	<116	116-280	>280

Keeping in view the recommendations, micro- and secondary nutrients were included in fertilizer management practices while conducting crop demonstrations at the pilot sites. Results showed significant yield advantage (20%) in paddy, maize, millets and groundnut. However, the use of improved cultivars and soil test-based nutrient management almost doubled yields in pigeonpea compared to prevailing farmers' practices. Thus, soil health mapping and demonstrations clearly demonstrated a very sound case for scaling out nutrient management, improved varieties and best practices for sustainable growth in the agriculture sector in Odisha.

Soil test laboratories turn state-of-the-art referral laboratories

Precise analysis of soil is impeded by the lack of sufficient infrastructure in laboratories across the country in general and also in Odisha (Wani et al. 2016; Chander et al. 2018). Most laboratories cannot analyze boron, sulfur, and to some extent micronutrients like zinc, copper, iron and manganese. To cater to the state's need for precision in analyzing a large number of soil, water, fertilizer and plant samples in a short time span, a need was felt to upgrade two district laboratories in Odisha, one in Bhubaneshwar and the other in Sambalpur, into state-of-the-art referral laboratories conforming to international standards. ICRISAT along with OUAT and DoA are collectively working on this. A week-long orientation training on the use and maintenance of state-of-the-art equipment was conducted at the Charles Renard Analytical Laboratory at ICRISAT, Hyderabad, for key staff from the two laboratories, OUAT scientists, and other officials from DoA headquarters involved in key decision making.

Use of ICT for dissemination and impacts

As per the National Sample Survey (NSSO 2014), around 60% of farm households don't receive any assistance from either government or private sector extension agencies. Hence, it is imperative to reform knowledge delivery systems using modern tools of information and communication technology (Wani et al. 2018a).

A tablet or computer-based extension module is being piloted with the DoA involving extension staff across all the districts. The tablets are being used to disseminate soil analysis-based advisories and best crop management practices. Results of the analyses of 40,265 soil samples were interpolated to develop interactive digital maps on macro and micronutrients and other parameters like soil carbon, pH, and electrical conductivity (EC). The soil maps have been made available to farmers, extension agents and other stakeholders through Internet-based interactive tools to guide in on-site soil health management and input use. These maps can also serve as decision support tools for policy makers while allocating crop- and season-wise inputs and in the movement of fertilizers/nutrients across the state.

Capacity building and collective working

The huge knowledge gap between 'what to do' and 'how to do it' is a major reason for the gap between potential yield and actual yield realized on research farms (Wani et al. 2018a). Previous scaling-out programs owed their success to the emphasis on capacity building of stakeholders, which were instrumental in economic growth and development (Anantha et al. 2016). Together with consortium partners, the innovative approach of demonstrating and evaluating technologies in pilot sites was a step in this direction. In this process, the focus was on knowledge sharing and formal capacity building and training of lead farmers, NGO personnel and staff in line departments. Workshops with the DoA enabled the sharing of documented benefits realized at pilot sites, and to collectively work out the roadmap for scaling-out proven technologies.

The Odisha *Bhoochetana* program envisages the involvement of many stakeholders, both in formal and informal sectors. ICRISAT entered into partnerships with more than 20 NGOs to solicit field level support and to reach out to a large number of farmers in the district. OUAT is a close partner in soil sampling, baseline studies, establishment of referral laboratories, devising fertilizer recommendations and evaluation of improved crop varieties in the pilot sites. ICAR-NRRI, Cuttack has been an important partner in building the capacities of field staff on scientific cultivation and management of improved rice cultivars. Such partnerships are instrumental in harnessing synergies.

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Chapter 2

Soil Sampling and Analysis

Girish Chander and Pushpajeet Choudhari

Soil sampling is one of the most important prerequisites to implement site-specific nutrient management. It is also the weakest link in the whole chain of soil test-based nutrient management. A small quantity of soil (about 500 g) collected should truly represent the millions of tons of soil in a field. Hence, utmost care should be taken during collection to secure accurate results.

Stratified soil sampling

In order to diagnose soil fertility-related constraints, about 40,265 soil samples were collected from farmers' fields across 30 districts of Odisha. Stratified soil sampling method (Sahrawat et al. 2008, 2011; Chander et al. 2013) was adopted, wherein 10% of the villages that are representative of the agro-climate of a block were selected and 10 soil samples were collected from each village. The target village was divided into three toposequences, and at each toposequence, samples were drawn proportionately representing different farm sizes, soil colour, texture, cropping system and land management practices. In each soil sample collected in each farmer's field, 8 to 10 cores of soil from a depth of 0–0.15 cm were collected and mixed together to make a composite sample. All the samples were collected during pre-monsoon season, i.e., April to June 2018. Details of the samples collected district-wise and block-wise are given in Table 2.1 and Annexure 1, respectively.

Soil sample preparation and analysis

Under the Odisha *Bhoochetana* project, 40,265 geo-referenced soil samples were collected from different farmer's fields across 30 districts. The sample bags were properly tagged, labelled and transferred to the ICRISAT processing unit. The soil samples were air dried and the clods ground using a wooden mortar and pestle. The sample was then passed through a 2 mm sieve. For organic carbon analysis, the samples were further ground and passed through a 0.25 mm sieve. The processed samples were analyzed for 13 chemical parameters in ICRISAT's Charles Renard Analytical Laboratory.

For soil analysis, pH was measured by a glass electrode using a soil-water suspension in the ratio of 1:2 (Thomas 1996) and EC was measured with the same suspension after settling the sample overnight using an EC meter (Rhoades 1996). Organic carbon was determined using the Walkley-Black method (Nelson and Sommers, 1996). Exchangeable bases, i.e., K, Ca and Mg were determined using neutral normal ammonium acetate method (Okalebo et al. 1993). Available P was estimated using Brays Extractant No. 1, 0.03M NH_4F in 0.025M HCl (Bray and Kurtz, 1945) for acidic soils and sodium bicarbonate ($NaHCO_3$) of pH 8.5 as an extractant (Olsen and Sommers, 1982) in the case of alkaline soils. Available micronutrients, i.e., Fe, Cu, Mn and Zn were extracted by DTPA reagent of pH 7.3 (Lindsay and Norvell, 1978) and available B was extracted by hot water (Keren 1996). Available S was measured using 0.15% calcium chloride ($CaCl_2$) as an extractant (Tabatabai 1996). Macro and micronutrients were measured on Microwave Plasma Atomic Emission Spectroscopy whereas, Boron and Sulphur were measured through the Inductively Coupled Plasma-Optical Emission Spectroscopy (ICP-OES).

Table 2.1. Details of the district-wise soil sampling done across 30 districts in Odisha.

District	Number of blocks	Number of villages	Number of soil samples collected
Angul	8	104	1020
Baleswar	12	156	1550
Bargarh	12	156	1550
Bhadrak	7	91	910
Balangir	14	182	1819
Boudh	3	39	370
Cuttak	14	182	1820
Deogarh	3	39	390
Dhenkanal	8	104	1030
Gajapati	7	91	939
Ganjam	22	286	2810
Jagatsinghpur	8	104	1040
Jajpur	10	130	1300
Jharsuguda	5	65	650
Kalahandi	13	169	1670
Kandhamal	12	156	1554
Kendrapara	9	117	1150
Kendujhar	13	169	1540
Khorda	10	130	1300
Koraput	11	182	1769
Malkangiri	6	91	937
Mayurbhanj	26	338	3317
Nabarangpur	10	130	1213
Nayagarh	8	104	1040
Nuapada	5	65	647
Puri	11	143	1420
Rayagada	10	143	1430
Sambalpur	9	117	1170
Subarnapur	6	78	780
Sundargarh	17	221	2130
Total	309	4082	40,265

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Annexure

Annexure 1. Details of block-wise soil sampling done across 30 districts in Odisha.

District	Block	Number of villages chosen for sampling	Number of soil samples collected
Angul	Angul	15	150
Angul	Athamallik	15	130
Angul	Banarpal	9	90
Angul	Chendipada	10	100
Angul	Kanhia	15	150
Angul	Kishorenagar	15	150
Angul	Pallahara	15	150
Angul	Talcher	10	100
Total	**8**	**104**	**1020**
Baleswar	Bahanoga	10	100
Baleswar	Baleswar	15	150
Baleswar	Baliapal	15	150
Baleswar	Basta	10	100
Baleswar	Bhogarai	16	160
Baleswar	Jaleswar	15	150
Baleswar	Khaira	20	200
Baleswar	Nilagiri	10	100
Baleswar	Oupada	10	100
Baleswar	Remuna	15	140
Baleswar	Simulia	10	100
Baleswar	Soro	10	100
Total	**12**	**156**	**1550**
Bargarh	Ambabhona	16	160
Bargarh	Atabira	15	150
Bargarh	Bargarh	10	90
Bargarh	Barpali	10	100
Bargarh	Bhatli	10	100
Bargarh	Bheden	10	100
Bargarh	Bijepur	15	150
Bargarh	Gaisilat	10	100
Bargarh	Jharbandh	10	100
Bargarh	Padmapur	20	200
Bargarh	Paikamal	15	150
Bargarh	Sohella	15	150
Total	**12**	**156**	**1550**

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Annexure 1. Details of block-wise soil sampling done across 30 districts in Odisha.

District	Block	Number of villages chosen for sampling	Number of soil samples collected
Bhadrak	Basudevpur	15	150
Bhadrak	Bhadrak	10	100
Bhadrak	Bhandaripokhari	12	120
Bhadrak	Bonth	15	150
Bhadrak	Chandabali	15	150
Bhadrak	Dhamanagar	12	120
Bhadrak	Tihidi	12	120
Total	**7**	**91**	**910**
Balangir	Agalapur	10	100
Balangir	Bangamunda	15	150
Balangir	Belapada	10	100
Balangir	Balangir	12	120
Balangir	Deogam	15	149
Balangir	Gudvella	10	100
Balangir	Kaprakhole	15	150
Balangir	Luisinga	10	100
Balangir	Muribahal	15	150
Balangir	Patnagarh	15	150
Balangir	Puintala	15	150
Balangir	Saintala	15	150
Balangir	Titilagarh	15	150
Balangir	Turekela	10	100
Total	**14**	**182**	**1819**
Boudh	Boudh	14	130
Boudh	arbhanga	10	90
Boudh	Kantamal	15	150
Total	3	39	370
Cuttack	Athagarh	20	200
Cuttack	Banki	12	120
Cuttack	Banki-Dampada	10	100
Cuttack	Baramba	5	50
Cuttack	Baranga	8	80
Cuttack	Choudwar	16	160
Cuttack	Cuttack Sadar	10	100
Cuttack	Kantapada	10	100

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Annexure 1. Details of block-wise soil sampling done across 30 districts in Odisha.

District	Block	Number of villages chosen for sampling	Number of soil samples collected
Cuttack	Mahanga	20	200
Cuttack	Narasinghpur	20	200
Cuttack	Niali	10	100
Cuttack	Nischantakoili	20	200
Cuttack	Salepur	16	160
Cuttack	Tigiria	5	50
Total	**14**	**182**	**1820**
Deogarh	Barkote	9	90
Deogarh	Reamal	20	200
Deogarh	Tileibani	10	100
Total	**3**	**39**	**390**
Dhenkanal	Bhuban	10	100
Dhenkanal	Dhenkanal (Sadar)	15	150
Dhenkanal	Gondia	15	150
Dhenkanal	Hindol	15	150
Dhenkanal	Kamakhyanagar	10	100
Dhenkanal	Kankadahad	14	140
Dhenkanal	Odapada	10	100
Dhenkanal	Parjang	15	140
Total	**8**	**104**	**1030**
Gajapati	Gumma	15	150
Gajapati	Kasinagar	10	80
Gajapati	Mohana	20	190
Gajapati	Nuagada	12	159
Gajapati	Paralakhemundi	10	100
Gajapati	Udayagiri	12	140
Gajapati	7. Rayagada	12	120
Total	**7**	**91**	**939**
Ganjam	Aska	10	100
Ganjam	Beguniapada	15	150
Ganjam	Belguntha	10	80
Ganjam	Bhanjanagar	15	150
Ganjam	Buguda	10	100
Ganjam	Chatrapur	10	100
Ganjam	Chikiti	10	100

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Annexure 1. Details of block-wise soil sampling done across 30 districts in Odisha.

District	Block	Number of villages chosen for sampling	Number of soil samples collected
Ganjam	Dharakote	16	160
Ganjam	Digipahandi	20	200
Ganjam	Ganjam	10	100
Ganjam	Hinjilikatu	5	50
Ganjam	Jagannath Prasad	25	250
Ganjam	Kabisuryanagar	5	50
Ganjam	Khallikote	10	100
Ganjam	Kukudakhandi	10	100
Ganjam	Patrapur	25	250
Ganjam	Polsara	10	100
Ganjam	Purusottampur	10	100
Ganjam	Rangeilunda	10	100
Ganjam	Sanakhemundi	10	100
Ganjam	Sheragada	10	100
Ganjam	Sorada	30	270
Total	**22**	**286**	**2810**
Jagatsinghpur	Balikuda	20	200
Jagatsinghpur	Biridi	8	80
Jagatsinghpur	Ersama	15	150
Jagatsinghpur	Jagatsinghpur	15	150
Jagatsinghpur	Kujang	10	100
Jagatsinghpur	Naugaon	8	80
Jagatsinghpur	Raghunathpur	8	80
Jagatsinghpur	Tirtol	20	200
Total	**8**	**104**	**1040**
Jajpur	Barchana	15	150
Jajpur	Bari	10	100
Jajpur	Binjharpur	10	100
Jajpur	Dangadi	10	100
Jajpur	Dasarathpur	15	150
Jajpur	Dharmasala	15	150
Jajpur	Jajpur	15	150
Jajpur	Korei	15	150
Jajpur	Rasulpur	15	150
Jajpur	Sukinda	10	100

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Annexure 1. Details of block-wise soil sampling done across 30 districts in Odisha.

District	Block	Number of villages chosen for sampling	Number of soil samples collected
Total	**10**	**130**	**1300**
Jharsuguda	Jharsuguda	15	150
Jharsuguda	Kirmira	10	100
Jharsuguda	Kolabira	10	100
Jharsuguda	Laikera	10	100
Jharsuguda	Lakhanpur	20	200
Total	**5**	**65**	**650**
Kalahandi	Bhawanipatna	20	200
Kalahandi	Dharmagarh	10	100
Kalahandi	Golamunda	10	100
Kalahandi	Jaipatna	8	80
Kalahandi	Junagarh	15	150
Kalahandi	Kalampur	5	50
Kalahandi	Karlamunda	6	60
Kalahandi	Kesinga	10	90
Kalahandi	Koksara	7	70
Kalahandi	Lanjigarh	25	240
Kalahandi	Madanpur Rampur	25	250
Kalahandi	Narla	10	100
Kalahandi	Thuamul Rampur	18	180
Total	**13**	**169**	**1670**
Kandhamal	Balliguda	15	149
Kandhamal	Chakapad	10	100
Kandhamal	Daringbadi	15	140
Kandhamal	G.Udayagiri	10	100
Kandhamal	K.Nuagaon	10	100
Kandhamal	Khajuripada	15	150
Kandhamal	Kotgarh	10	100
Kandhamal	Phiringia	20	199
Kandhamal	Phulbani	15	150
Kandhamal	Raikia	11	110
Kandhamal	Tikabali	10	106
Kandhamal	Tumudibandh	15	150
Total	**12**	**156**	**1554**

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Annexure 1. Details of block-wise soil sampling done across 30 districts in Odisha.			
District	**Block**	**Number of villages chosen for sampling**	**Number of soil samples collected**
Kendrapara	Aul	10	100
Kendrapara	Derabish	15	140
Kendrapara	Garadpur	10	100
Kendrapara	Kendrapara	10	100
Kendrapara	Mahakalapara	20	200
Kendrapara	Marsaghai	10	100
Kendrapara	Pattamundai	10	100
Kendrapara	Rajkanika	10	90
Kendrapara	Rajnagar	22	220
Total	**9**	**117**	**1150**
Kendujhar	Anandapur	12	120
Kendujhar	Bansalpal	15	150
Kendujhar	Champua	12	120
Kendujhar	Ghasipura	12	120
Kendujhar	Ghatgaon	11	110
Kendujhar	Harichandanpur	20	200
Kendujhar	Hatadihi	15	150
Kendujhar	Jhumpura	12	120
Kendujhar	Joda	10	50
Kendujhar	Kendujhar (Sadar)	20	100
Kendujhar	Patna	10	100
Kendujhar	Saharapada	10	100
Kendujhar	Telkoi	10	100
Total	**13**	**169**	**1540**
Khorda	Balianta	10	100
Khorda	Balipatna	12	120
Khorda	Banapur	15	150
Khorda	Begunia	15	150
Khorda	Bhubaneswar	10	100
Khorda	Bolagad	20	200
Khorda	Chilika	13	130
Khorda	Jatni	10	100
Khorda	Khorda	10	100
Khorda	Tangii	15	150
Total	**10**	**130**	**1300**

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Annexure 1. Details of block-wise soil sampling done across 30 districts in Odisha.

District	Block	Number of villages chosen for sampling	Number of soil samples collected
Koraput	Bandhugaon	15	
Koraput	Boipariguda	20	
Koraput	Boriguma	15	220
Koraput	Dasamanthpur	16	60
Koraput	Jeypore	10	100
Koraput	Koraput	10	140
Koraput	Kotpad	10	210
Koraput	Kundra	10	100
Koraput	Lamptaput	16	189
Koraput	Laxmipur	10	100
Koraput	Nandapur	20	450
Koraput	Narayanapatna	10	
Koraput	Pottangi	10	100
Koraput	Semiliguda	10	100
	Total	**182**	**1769**
Malkangiri	Kallimela	15	129
Malkangiri	Khairaput	10	100
Malkangiri	Korukonda	15	148
Malkangiri	Kudmulgumma	15	300
Malkangiri	Malkangiri	10	
Malkangiri	Mathili	20	200
Malkangiri	Podia	6	60
Total	**7**	**91**	**937**
Mayurbhanj	Badasahi	20	200
Mayurbhanj	Bahalda	10	90
Mayurbhanj	Bangiriposhi	20	200
Mayurbhanj	Baripada	10	100
Mayurbhanj	Betanati	25	250
Mayurbhanj	Bijatala	10	100
Mayurbhanj	Bisoi	15	150
Mayurbhanj	Gopabandhunagar	10	100
Mayurbhanj	Jamda	5	50
Mayurbhanj	Joshipur	20	200
Mayurbhanj	Kaptipada	10	100
Mayurbhanj	Karanjia	15	140
Mayurbhanj	Khunta	10	100

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Annexure 1. Details of block-wise soil sampling done across 30 districts in Odisha.

District	Block	Number of villages chosen for sampling	Number of soil samples collected
Mayurbhanj	Kuliana	20	200
Mayurbhanj	Kusumi	10	99
Mayurbhanj	Moroda	15	150
Mayurbhanj	Rairangapur	10	90
Mayurbhanj	Raruan	10	100
Mayurbhanj	Rasagobindapur	15	150
Mayurbhanj	Samakhunta	10	99
Mayurbhanj	Sarasakana	15	150
Mayurbhanj	Sukuruli	8	79
Mayurbhanj	Suliapada	20	170
Mayurbhanj	Thakurmunda	15	150
Mayurbhanj	Tiring	5	50
Mayurbhanj	Udala	5	50
Total	**26**	**338**	**3317**
Nabarangpur	Chandahandi	10	100
Nabarangpur	Dabugaon	15	148
Nabarangpur	Jharigaon	10	101
Nabarangpur	Kosagumuda	15	119
Nabarangpur	Nandahandi	10	88
Nabarangpur	Nabarangpur	10	100
Nabarangpur	Papadahandi	10	100
Nabarangpur	Raighar	20	161
Nabarangpur	Tentulikhunti	20	198
Nabarangpur	Umerkote	10	98
Total	**10**	**130**	**1213**
Nayagarh	Bhapur	10	100
Nayagarh	Daspalla	20	200
Nayagarh	Gania	10	100
Nayagarh	Khandapada	12	120
Nayagarh	Nayagarh	10	100
Nayagarh	Nuagaon	12	120
Nayagarh	Odagaon	15	150
Nayagarh	Ranpur	15	150
Total	**8**	**104**	**1040**

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Annexure 1. Details of block-wise soil sampling done across 30 districts in Odisha.

District	Block	Number of villages chosen for sampling	Number of soil samples collected
Nuapada	Boden	10	100
Nuapada	Khariar	10	100
Nuapada	Komna	15	150
Nuapada	Nuapada	15	147
Nuapada	Sinapali	15	150
Total	**5**	**65**	**647**
Puri	Astarang	10	100
Puri	Brahmagiri	15	150
Puri	Delang	10	90
Puri	Gop	15	150
Puri	Kakatpur	10	100
Puri	Kanas	15	150
Puri	Krushnaprasad	10	100
Puri	Nimapada	18	180
Puri	Pipili	15	150
Puri	Puri Sadar	10	100
Puri	Satyabadi	15	150
Total	**11**	**143**	**1420**
Rayagada	Bissamcuttack	10	130
Rayagada	Chandrapur	10	100
Rayagada	Gudari	10	100
Rayagada	Gunupur	20	190
Rayagada	Kalyansinghpur	13	130
Rayagada	Kashipur	20	200
Rayagada	Kolanara	10	100
Rayagada	Muniguda	20	200
Rayagada	Ramanaguda	10	
Rayagada	Rayagada	20	180
Rayagada	Padmapur		100
Total	**11**	**143**	**1430**
Sambalpur	Bamara	15	150
Sambalpur	Dhankauda	10	100
Sambalpur	Jamanakira	25	250
Sambalpur	Jujomora	10	100
Sambalpur	Kuchinda	10	100

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Annexure 1. Details of block-wise soil sampling done across 30 districts in Odisha.

District	Block	Number of villages chosen for sampling	Number of soil samples collected
Sambalpur	Maneswar	10	100
Sambalpur	Naktideul	15	150
Sambalpur	Rairakhol	15	150
Sambalpur	Rengali	7	70
Total	**9**	**117**	**1170**
Subarnapur	Binka	9	90
Subarnapur	Birmaharajpur	13	130
Subarnapur	Dunguripalli	10	100
Subarnapur	Subarnapur	12	120
Subarnapur	Tarva	14	140
Subarnapur	Ulunda	20	200
Total	**6**	**78**	**780**
Sundargarh	Badagaon	10	100
Sundargarh	Balisankara	10	100
Sundargarh	Banaigarh	16	100
Sundargarh	Bisra	10	300
Sundargarh	Gurundia	20	10
Sundargarh	Hemgiri	15	240
Sundargarh	Koira	10	10
Sundargarh	Kuanrmunda	25	250
Sundargarh	Kutra	20	190
Sundargarh	Lahunipada	20	200
Sundargarh	Lathikata	10	100
Sundargarh	Lephripara	15	130
Sundargarh	Rajgangpur	10	100
Sundargarh	Subdega	10	100
Sundargarh	Sundargarh (Sadar)	10	100
Sundargarh	Tangarpalli	10	100
Total	**17**	**221**	**2130**

Chapter 3

Developing Soil Test-based Fertilizer Recommendations

Girish Chander, Pushpajeet Choudhari, Gajanan Sawargaonkar, Antaryami Mishra and Rabindra Kumar Nayak

Soil health mapping in the state of Odisha aimed at improving crop productivity and thereby the rural livelihoods of those depending on the agrarian economy. The activity began with the collection of 40,265 representative soil samples using stratified random sampling across 30 districts. This was a first of its kind, systematic exercise aimed at diagnosing soil fertility- related constraints in the state in order to ascertain macro and micronutrient deficiencies and develop practical recommendations for scaling-out.

Determining critical limits for nutrient indices

The critical limits that differentiate between nutrient deficiency and nutrient sufficiency are presented in Table 3.1. Based on these critical limits for each of the soil nutrient parameters, deficiency and sufficiency levels were worked out (Annexures 2 to 31) to facilitate data-driven decision support for soil health management across the districts.

Crop-wise nutrient recommendation

Based on the results of the soil analyses, fertilizer recommendations were worked out to facilitate the application of micronutrients such as sulfur, boron and zinc and secondary nutrients like nitrogen, phosphorus and potassium. Soil test-based fertilizer recommendations were made for individual farmers on whose lands sampling was done. For the non-sampled farmers, the recommendations were worked out based on the weighted average values derived at the respective villages or blocks based on soil test values of the 40,265 samples collected. For secondary and micronutrients, application of a full dose is

Table 3.1. Critical limits in soil nutrient parameters to differentiate between sufficiency and deficiency.

Parameter	Critical limit
Soil organic carbon	0.5%
pH	5.5-7.5 (neutral)
Electrical Conductivity (EC) (dS/m)	<1 (normal)
P_2O_5	10 ppm
K_2O	120 ppm
Exchangeable Calcium	1000 ppm
Exchangeable Magnesium	40 ppm
Available Sulfur	10 ppm
Exchangeable Zinc	0.6 ppm
Exchangeable Copper	0.2 ppm
Exchangeable Iron	4.5 ppm
Exchangeable Manganese	2 ppm
Available Boron	0.5 ppm

being recommended where the deficiency is more than 50% for that particular nutrient in a particular village or block; half the dose when the deficiency is between 25% and 50%, one fourth dose with 10-25% deficiency and no application where the deficiency level is less than 10% (Chander et al. 2016, 2019). The suggested full dose recommended for boron is 1 kg/ha. With regard to zinc, the recommended dose for paddy and pulses is 5 kg/ha and for other cereals and oilseed crops 2.5 kg/ha and 2 kg/ha, respectively (Anonymous 2019). However, with regard to recommendations for sulfur, the use of 30 kg/ha, 40 kg/ha and 45 kg/ha in the case of cereals, pulses and oilseed crops, respectively has been suggested.

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Annexure 2. Block-level deficiency of major and micronutrients and soil condition in Angul district.

Block	No of samples	Fields under various pH conditions (%)			Fields under normal EC* conditions (%)	Fields with low soil C levels and nutrient deficiencies (%)**										
		Neutral	Acidic	Alkaline		OC	P	K	Ca	Mg	S	Zn	B	Fe	Cu	Mn
Angul	150	51	29	21	100	42	45	7	0	11	46	62	76	3	0	7
Athmalik	130	47	31	22	100	37	42	9	5	24	28	55	70	2	0	2
Banarpal	90	44	30	26	100	39	39	1	0	9	13	56	73	3	1	16
Chhendipada	100	60	22	18	100	33	43	13	9	34	24	82	70	11	7	23
Kaniha	150	93	5	1	100	34	49	25	11	35	33	76	80	1	2	17
Kishornagar	150	80	15	5	100	27	65	12	9	25	34	72	95	4	12	4
Pallahara	150	93	6	1	100	33	60	7	9	26	69	47	95	0	0	1
Talcher	100	65	33	2	100	24	37	12	4	23	23	37	69	1	0	3

*EC = Electrical Conductivity.

**OC = Organic Carbon, P = Phosphorous, K= Potassium, Ca= Calcium, Mg = Magnesium, S = Sulfur, Zn = Zinc, B = Boron, Fe = Iron, Cu = Copper and Mn = Manganese.

Annexure 3. Block-level deficiency of major and micronutrients and soil condition in Baleswar district.

Block	No of samples	Fields under various pH conditions (%)			Fields under normal EC* conditions (%)	Fields with low soil C levels and nutrient deficiencies (%)**										
		Acidic	Neutral	Alkaline		OC	P	K	Ca	Mg	S	Zn	B	Fe	Cu	Mn
Bahanoga	100	100	0	0	100	65	55	77	10	44	55	72	91	0	0	1
Baleswar Sadar	150	98	2	0	99	32	60	51	17	30	44	33	61	2	1	4
Baliapal	150	55	43	1	99	42	23	31	7	23	20	44	32	19	6	9
Basta	100	70	29	1	99	13	28	12	7	9	12	49	15	3	0	3
Bhogarai	160	79	17	4	100	51	44	43	29	35	19	34	39	1	6	19
Jaleswar	150	85	15	0	100	44	27	18	5	9	41	10	49	7	0	0
Khaira	200	93	7	1	100	71	55	61	5	47	48	43	90	3	2	2
Nilagiri	100	96	4	0	100	53	70	46	10	27	40	32	98	1	3	2
Oupada	100	90	10	0	100	44	53	46	18	37	53	35	90	1	10	0
Remuna	140	89	11	0	99	59	56	63	16	34	38	46	85	2	0	6
Simulia	100	87	4	9	100	75	62	51	3	27	38	75	93	9	8	11
Soro	100	90	9	1	98	73	69	65	6	50	44	46	93	4	3	11

*EC = Electrical Conductivity.

**OC = Organic Carbon, P = Phosphorous, K= Potassium, Ca= Calcium, Mg = Magnesium, S = Sulfur, Zn = Zinc, B = Boron, Fe = Iron, Cu = Copper and Mn = Manganese.

Annexure 4. Block-level deficiency of major and micronutrients and soil condition in Bargarh district.

Block	No of samples	Fields under various pH conditions (%)			Fields under normal EC* conditions (%)	Fields with low soil C levels and nutrient deficiencies (%)**										
		Acidic	Neutral	Alkaline		OC	P	K	Ca	Mg	S	Zn	B	Fe	Cu	Mn
Ambabhona	160	85	15	0	100	23	17	15	3	33	23	34	79	0	0	0
Atabira	150	94	5	1	100	37	23	51	5	45	21	53	97	0	1	4
Bargarh	90	74	12	13	100	37	21	41	6	68	21	37	96	1	7	4
Barpali	100	85	14	1	99	34	33	39	5	33	28	60	94	2	4	2
Bhatli	100	96	4	0	100	51	15	46	22	82	23	45	98	0	6	1
Bheden	100	88	12	0	98	49	31	46	8	44	29	52	88	1	1	4
Bijepur	150	88	10	2	100	39	44	18	12	46	23	49	86	1	2	3
Gaisilat	100	59	27	14	100	34	42	12	6	17	22	58	85	2	1	1
Jharabandha	100	53	29	17	100	28	53	14	3	12	31	64	92	4	2	2
Padampur	200	74	20	6	100	32	47	14	7	23	36	64	91	2	6	3
Paikamal	150	74	19	7	100	30	62	9	2	20	49	51	89	3	1	1
Sohela	150	77	18	5	100	47	42	27	13	46	31	69	92	1	3	4

*EC = Electrical Conductivity.

**OC = Organic Carbon, P = Phosphorous, K= Potassium, Ca= Calcium, Mg = Magnesium, S = Sulfur, Zn = Zinc, B = Boron, Fe = Iron, Cu = Copper and Mn = Manganese.

Annexure 5. Block-level deficiency of major and micronutrients and soil condition in Bhadrak district.

Block	No of samples	Fields under various pH conditions (%)			Fields under normal EC* conditions (%)	Fields with low soil C levels and nutrient deficiencies (%)**										
		Acidic	Neutral	Alkaline		OC	P	K	Ca	Mg	S	Zn	B	Fe	Cu	Mn
Basudevpur	150	91	9	0	99	39	15	43	6	13	29	52	50	0	1	3
Bhadaripokhari	120	98	0	2	100	66	55	20	0	0	80	58	78	1	0	0
Bhadrak	100	76	15	9	99	37	38	31	5	11	59	35	83	4	0	4
Bonth	150	90	10	0	100	46	59	25	0	1	77	35	70	0	0	0
Chandabali	150	98	1	1	97	19	45	4	0	0	13	36	6	0	0	0
Dhamanagar	120	100	0	0	100	38	40	32	0	0	60	33	84	0	0	0
Tihidi	120	98	2	0	100	43	38	19	0	0	33	15	47	0	0	0

*EC = Electrical Conductivity.

**OC = Organic Carbon, P = Phosphorous, K= Potassium, Ca= Calcium, Mg = Magnesium, S = Sulfur, Zn = Zinc, B = Boron, Fe = Iron, Cu = Copper and Mn = Manganese.

Annexure 6. Block-level deficiency of major and micronutrients and soil condition in Balangir district.

Block	No of samples	Fields under various pH conditions (%)			Fields under normal EC* conditions (%)	Fields with low soil C levels and nutrient deficiencies %)**										
		Acidic	Neutral	Alkaline		OC	P	K	Ca	Mg	S	Zn	B	Fe	Cu	Mn
Agalpur	100	66	18	16	100	75	76	12	14	35	43	92	97	26	23	10
Bangomunda	150	41	31	28	100	52	60	9	2	10	38	73	91	10	5	9
Belpada	100	82	15	3	100	36	82	18	7	30	59	75	100	1	6	0
Balangir	120	48	34	18	100	32	58	11	0	5	34	64	87	3	0	5
Degaon	149	58	28	14	100	47	68	19	3	23	50	92	97	3	3	3
Gudbhela	100	58	20	22	100	37	52	9	0	11	48	72	96	7	4	6
Khaprakhol	150	61	23	15	100	34	73	12	2	9	60	85	98	3	3	6
Loisinga	100	29	41	30	100	36	54	21	1	10	23	69	89	10	2	6
Muribahal	150	80	15	5	100	46	72	27	7	39	64	75	95	4	8	1
Patnagarh	150	65	26	9	100	49	73	15	6	24	47	82	97	8	5	2
Puintala	150	37	33	29	100	37	65	15	1	3	27	82	78	9	1	29
Saintala	150	83	13	4	100	61	81	21	11	38	61	86	97	1	10	4
Titilagarh	150	61	27	12	100	57	59	15	3	46	31	45	88	4	8	4
Tureikela	100	42	41	17	100	42	81	15	1	9	18	67	84	0	0	13

*EC = Electrical Conductivity.

**OC = Organic Carbon, P = Phosphorous, K= Potassium, Ca= Calcium, Mg = Magnesium, S = Sulfur, Zn = Zinc, B = Boron, Fe = Iron, Cu = Copper and Mn = Manganese.

Annexure 7. Block-level deficiency of major and micronutrients and soil condition in Boudh district.

Block	No of samples	Fields under various pH conditions (%)			Fields under normal EC* conditions (%)	Fields with low soil C levels and nutrient deficiencies (%)**										
		Acidic	Neutral	Alkaline		OC	P	K	Ca	Mg	S	Zn	B	Fe	Cu	Mn
Boudh	130	57	26	17	100	54	58	38	6	29	52	71	97	7	2	11
Harabhanga	90	62	28	9	100	53	43	23	0	8	56	54	86	8	0	4
Kantamal	150	54	33	13	100	47	49	25	7	21	49	69	96	8	3	3

*EC = Electrical Conductivity.

**OC = Organic Carbon, P = Phosphorous, K= Potassium, Ca= Calcium, Mg = Magnesium, S = Sulfur, Zn = Zinc, B = Boron, Fe = Iron, Cu = Copper and Mn = Manganese.

Annexure 8. Block-level deficiency of major and micronutrients and soil condition in Cuttack district.

Block	No of samples	Fields under various pH conditions (%)			Fields under normal EC* conditions (%)	Fields with low soil C levels and nutrient deficiencies (%)**										
		Acidic	Neutral	Alkaline		OC	P	K	Ca	Mg	S	Zn	B	Fe	Cu	Mn
Athgarh	200	50	30	20	100	49	8	4	1	7	4	16	64	1	0	1
Banki	120	99	1	0	100	28	8	18	3	8	62	3	96	0	0	0
Banki-Dampada	100	96	4	0	100	39	25	52	12	19	43	0	85	0	1	1
Baramba	50	82	18	0	100	34	60	24	0	2	54	40	86	0	0	0
Baranga	80	98	2	0	100	64	44	43	1	11	60	31	96	0	0	0
Choudwar	160	98	2	0	100	47	56	21	4	13	38	1	89	1	0	1
Cuttack Sadar	100	94	6	0	98	44	19	50	0	9	36	10	90	0	0	0
Kantapada	100	92	0	8	100	29	60	45	1	6	67	12	90	8	1	7
Mahanga	200	98	2	0	100	18	24	23	0	0	26	8	69	0	0	0
Narsinghpur	200	69	22	9	100	23	35	9	1	11	43	14	79	1	0	1
Niali	100	97	3	0	100	46	39	47	1	7	79	17	94	0	0	0
Nishantakoili	200	94	4	2	100	36	49	59	1	4	46	51	84	1	0	1
Salepur	160	96	4	0	100	46	43	66	0	7	38	33	84	0	0	0
Tigiria	50	98	2	0	100	34	42	38	0	10	34	16	88	2	0	0

*EC = Electrical Conductivity.

**OC = Organic Carbon, P = Phosphorous, K= Potassium, Ca= Calcium, Mg = Magnesium, S = Sulfur, Zn = Zinc, B = Boron, Fe = Iron, Cu = Copper and Mn = Manganese.

Annexure 9. Block-level deficiency of major and micronutrients and soil condition in Deogarh district.

Block	No of samples	Fields under various pH conditions (%)			Fields under normal EC* conditions (%)	Fields with low soil C levels and nutrient deficiencies (%)**										
		Acidic	Neutral	Alkaline		OC	P	K	Ca	Mg	S	Zn	B	Fe	Cu	Mn
Barkote	90	98	2	0	100	23	87	33	12	29	70	61	93	2	1	1
Reamal	200	81	18	2	100	28	65	12	1	13	33	50	65	1	1	1
Tileibani	100	90	9	1	100	35	43	16	7	32	37	59	82	3	2	0

*EC = Electrical Conductivity.

**OC = Organic Carbon, P = Phosphorous, K= Potassium, Ca= Calcium, Mg = Magnesium, S = Sulfur, Zn = Zinc, B = Boron, Fe = Iron, Cu = Copper and Mn = Manganese.

Annexure 10. Block-level deficiency of major and micronutrients and soil condition in Dhenkanal district.

Block	No of samples	Fields under various pH conditions (%)			Fields under normal EC* conditions (%)	Fields with low soil C levels and nutrient deficiencies (%)**										
		Acidic	Neutral	Alkaline		OC	P	K	Ca	Mg	S	Zn	B	Fe	Cu	Mn
Bhuban	100	99	1	0	100	42	38	45	6	23	55	33	90	0	0	1
Dhenkanal (Sadar)	150	90	9	1	100	49	51	15	9	37	68	24	84	1	0	0
Gondia	150	93	7	0	100	31	63	16	1	17	47	19	79	0	0	0
Hindol	150	56	36	8	100	25	40	5	1	3	10	23	53	3	1	7
Kamakhyanagar	100	86	9	5	100	20	68	22	2	4	47	16	80	0	0	1
Kankadahad	140	91	7	1	100	24	69	37	8	28	60	16	69	1	0	4
Odapada	100	83	16	1	100	23	38	6	2	17	23	6	75	2	0	0
Parjang	140	66	24	10	100	39	74	9	0	8	24	13	71	0	0	0

*EC = Electrical Conductivity.

**OC = Organic Carbon, P = Phosphorous, K= Potassium, Ca= Calcium, Mg = Magnesium, S = Sulfur, Zn = Zinc, B = Boron, Fe = Iron, Cu = Copper and Mn = Manganese.

Annexure 11. Block-level deficiency of major and micronutrients and soil condition in Gajapati district.

Block	No of samples	Fields under various pH conditions (%)			Fields under normal EC* conditions (%)	Fields with low soil C levels and nutrient deficiencies (%)**										
		Acidic	Neutral	Alkaline		OC	P	K	Ca	Mg	S	Zn	B	Fe	Cu	Mn
Gosani	100	82	8	10	100	86	76	10	45	75	91	67	93	10	0	5
Gumma	150	95	4	1	100	56	58	13	28	67	75	41	93	0	1	3
Kasinagar	80	99	1	0	100	68	45	13	28	48	66	48	84	0	3	5
Nuagada	159	97	3	1	100	33	44	3	14	68	69	28	82	1	4	0
R.Udayagiri	140	89	4	7	100	79	56	2	66	83	84	54	92	8	2	0
Rayagada	120	99	1	0	100	45	14	3	33	94	73	21	98	0	0	1
Mohana	190	94	5	1	100	35	59	4	16	45	61	38	74	1	2	1

*EC = Electrical Conductivity.

**OC = Organic Carbon, P = Phosphorous, K= Potassium, Ca= Calcium, Mg = Magnesium, S = Sulfur, Zn = Zinc, B = Boron, Fe = Iron, Cu = Copper and Mn = Manganese.

Annexure 12. Block-level deficiency of major and micronutrients and soil condition in Ganjam district.

Block	No of samples	Fields under various pH conditions (%)			Fields under under EC* conditions (%)	Fields with low soil C levels and nutrient deficiencies (%)**										
		Acidic	Neutral	Alkaline		OC	P	K	Ca	Mg	S	Zn	B	Fe	Cu	Mn
Aska	100	80	11	9	100	52	72	35	1	9	68	55	73	4	0	2
Beguniapada	150	86	13	1	100	54	71	26	13	47	29	43	81	0	1	5
Bellaguntha	80	88	9	4	100	48	28	11	0	28	64	23	79	0	0	0
Bhanjanagar	150	86	11	3	100	33	75	9	5	18	59	23	82	0	0	0
Buguda	100	82	12	6	100	48	58	17	0	26	46	17	77	0	1	2
Chhatrapur	100	79	13	8	100	51	51	33	4	42	31	18	47	0	0	1
Chikiti	100	72	15	13	100	34	53	16	15	29	25	30	53	0	0	10
Dharakote	160	72	21	7	100	50	51	19	8	18	56	43	79	0	0	7
Digapahandi	200	62	34	4	100	41	83	11	0	11	27	39	73	0	0	3
Ganjam	100	34	48	18	71	53	31	3	1	6	8	13	6	0	0	9
Hinjilicut	50	60	28	12	98	70	46	32	18	28	42	44	52	0	0	0
J.N.Prasad	250	79	16	4	100	34	63	11	9	27	52	28	76	0	0	6
K.S.Nagar	50	68	16	16	100	58	62	24	2	16	32	26	64	2	0	2
Khalikote	100	85	10	5	100	53	86	29	12	30	32	15	66	1	0	3
Kukudakhandi	100	72	22	6	100	39	45	11	6	25	20	4	50	2	0	2
Patrapur	250	60	28	12	100	58	61	10	1	16	43	23	65	0	0	2
Polasara	100	78	19	3	100	18	80	20	3	14	40	49	73	0	0	1
Purusottampur	100	85	14	1	100	50	16	15	0	24	29	22	58	0	0	9
Rangeilunda	100	71	24	5	100	35	50	17	4	15	12	40	20	2	0	1
Sanakhemundi	100	61	30	9	100	44	49	16	9	25	45	47	67	2	0	1
Sheragada	100	41	43	16	100	60	23	1	0	1	30	34	27	2	0	0
Surada	270	58	29	13	100	40	39	4	6	18	50	49	71	6	0	4

*EC = Electrical Conductivity.

**OC = Organic Carbon, P = Phosphorous, K= Potassium, Ca= Calcium, Mg = Magnesium, S = Sulfur, Zn = Zinc, B = Boron, Fe = Iron, Cu = Copper and Mn = Manganese.

Annexure 13. Block-level deficiency of major and micronutrients and soil condition in Jagatsinghpur district.

Block	No of samples	Fields under various pH conditions (%)			Fields under normal EC* conditions (%)	Fields with low soil C levels and nutrient deficiencies (%)**										
		Acidic	Neutral	Alkaline		OC	P	K	Ca	Mg	S	Zn	B	Fe	Cu	Mn
Balikuda	200	99	1	1	100	44	29	15	1	3	59	53	35	0	0	1
Biridi	80	99	1	0	100	53	33	49	0	6	38	70	75	0	0	1
Erasama	150	92	7	1	99	63	65	21	7	4	47	57	39	2	0	10
Jagatsinghpur	150	92	8	0	100	43	42	30	3	4	65	68	81	1	1	3
Kujanga	100	99	1	0	97	30	19	9	0	1	49	23	50	0	0	0
Naugaon	80	96	4	0	100	50	15	23	3	4	68	40	79	0	0	0
Raghunathpur	80	94	6	0	100	48	35	43	0	3	89	91	96	0	0	0
Tirtol	200	99	2	0	100	33	15	39	0	2	56	50	79	0	0	0

*EC = Electrical Conductivity.

**OC = Organic Carbon, P = Phosphorous, K= Potassium, Ca= Calcium, Mg = Magnesium, S = Sulfur, Zn = Zinc, B = Boron, Fe = Iron, Cu = Copper and Mn = Manganese.

Annexure 14. Block-level deficiency of major and micronutrients and soil condition in Jajpur district.

Block	No of samples	Fields under various pH conditions (%)			Fields under normal EC* conditions (%)	Fields with low soil C levels and nutrient deficiencies (%)**										
		Acidic	Neutral	Alkaline		OC	P	K	Ca	Mg	S	Zn	B	Fe	Cu	Mn
Barchana	150	94	1	4	100	28	27	11	1	6	45	25	63	3	3	3
Bari	100	95	4	1	100	59	49	55	6	21	59	44	83	1	3	0
Binjharpur	100	99	1	0	100	41	61	51	4	8	59	43	84	0	2	0
Dangadi	100	93	6	0	100	42	76	47	3	15	84	13	90	0	0	0
Dasaratpur	150	78	13	9	80	20	44	19	2	3	28	9	25	13	0	15
Dharmasala	150	95	5	0	100	56	24	45	1	15	44	25	77	0	0	0
Jajpur	150	100	0	0	100	39	9	3	0	0	10	1	81	0	1	0
Korei	150	95	3	1	100	75	35	63	19	53	59	27	89	0	0	1
Rasulour	150	100	0	0	87	87	10	71	13	38	55	42	97	0	0	1
Sukinda	100	81	13	6	98	43	65	25	5	16	47	35	95	6	0	8

*EC = Electrical Conductivity.

**OC = Organic Carbon, P = Phosphorous, K= Potassium, Ca= Calcium, Mg = Magnesium, S = Sulfur, Zn = Zinc, B = Boron, Fe = Iron, Cu = Copper and Mn = Manganese.

Annexure 15. Block-level deficiency of major and micronutrients and soil condition in Jharsuguda district.

Block	No of samples	Fields under various pH conditions (%)			Fields under normal EC* conditions (%)	Fields with low soil C levels and nutrient deficiencies (%)**										
		Acidic	Neutral	Alkaline		OC	P	K	Ca	Mg	S	Zn	B	Fe	Cu	Mn
Laikera	100	100	0	0	100	39	53	19	18	38	37	21	98	0	0	1
Lakhanpur	200	94	7	0	100	49	53	38	17	42	58	39	92	2	1	1
Jharsuguda	150	89	11	1	100	30	36	7	24	46	15	13	84	0	1	1
Kirmira	100	99	1	0	100	48	61	47	23	57	61	44	100	0	1	4
Kolabira	100	97	3	0	100	55	67	22	17	45	42	43	89	1	2	1

*EC = Electrical Conductivity.

**OC = Organic Carbon, P = Phosphorous, K= Potassium, Ca= Calcium, Mg = Magnesium, S = Sulfur, Zn = Zinc, B = Boron, Fe = Iron, Cu = Copper and Mn = Manganese.

Annexure 16. Block-level deficiency of major and micronutrients and soil condition in Kalahandi district.

Block	No of samples	Fields under various pH conditions (%)			Fields under normal EC* conditions (%)	Fields with low soil C levels and nutrient deficiencies (%)**										
		Acidic	Neutral	Alkaline		OC	P	K	Ca	Mg	S	Zn	B	Fe	Cu	Mn
Bhawanipatna	200	48	31	22	100	63	58	2	3	12	54	77	82	7	4	5
Dharmgarh	100	68	22	10	100	26	64	17	0	4	43	59	83	2	0	0
Golamunda	100	60	30	10	100	36	45	7	5	18	32	70	80	10	1	0
Jaipatna	80	71	24	5	100	36	44	6	3	18	58	18	74	6	0	0
Junagarh	150	82	15	3	100	59	83	7	1	31	43	31	94	1	0	3
Kalampur	50	90	10	0	100	28	78	28	0	0	82	26	100	0	0	0
Karlamunda	60	43	40	17	100	73	80	27	0	3	68	87	95	2	0	8
Kesinga	90	44	23	32	100	62	81	2	1	17	50	76	91	1	1	16
Koksara	70	71	23	6	100	43	84	6	1	7	46	63	86	0	0	4
Lanjigarh	240	72	22	6	100	57	63	12	1	22	63	38	71	1	0	1
M.Rampur	250	60	30	10	100	56	68	14	6	27	55	61	89	1	3	2
Narla	100	48	27	25	100	36	64	10	5	15	30	84	70	3	0	11
Thuamul Rampur	180	38	56	4	100	11	17	1	2	5	38	11	33	0	0	0

*EC = Electrical Conductivity.

**OC = Organic Carbon, P = Phosphorous, K= Potassium, Ca= Calcium, Mg = Magnesium, S = Sulfur, Zn = Zinc, B = Boron, Fe = Iron, Cu = Copper and Mn = Manganese.

Annexure 17. Block-level deficiency of major and micronutrients and soil condition in Kandhamal district.

Block	No of samples	Fields under various pH conditions (%)			Fields under normal EC* conditions (%)	Fields with low soil C levels and nutrient deficiencies (%)**										
		Acidic	Neutral	Alkaline		OC	P	K	Ca	Mg	S	Zn	B	Fe	Cu	Mn
Daringbadi	140	98	2	0	100	34	54	6	17	68	79	36	88	0	4	1
G.Udayagiri	100	94	5	1	100	32	62	5	12	74	80	23	89	0	1	0
K. Nuagaon	100	97	3	0	100	36	30	5	17	68	80	26	84	2	4	0
Khajuripada	150	89	11	0	100	41	47	15	5	45	65	41	86	6	6	1
Kotagarh	100	98	2	0	100	21	37	3	1	33	54	44	68	1	26	0
Phulbani	150	98	2	0	100	81	49	15	7	58	73	56	95	0	9	3
Raikia	110	98	2	0	100	40	63	15	12	69	56	34	90	1	5	0
Tikabali	106	85	14	1	100	64	40	4	7	48	59	37	91	4	2	0
Tumudibandha	150	95	3	1	100	43	68	30	1	33	93	52	94	2	1	0
Balliguda	149	93	6	1	100	36	54	5	9	51	64	35	90	3	4	0
Chakapad	100	95	5	0	100	35	28	13	11	55	66	24	84	0	5	0
Phiringia	199	97	7	1	100	25	57	7	2	38	74	53	80	2	2	0

*EC = Electrical Conductivity.

**OC = Organic Carbon, P = Phosphorous, K= Potassium, Ca= Calcium, Mg = Magnesium, S = Sulfur, Zn = Zinc, B = Boron, Fe = Iron, Cu = Copper and Mn = Manganese.

Annexure 18. Block-level deficiency of major and micronutrients and soil condition in Kendrapara district.

Block	No of samples	Fields under various pH conditions (%)			Fields under normal EC* conditions (%)	Fields with low soil C levels and nutrient deficiencies (%)**										
		Acidic	Neutral	Alkaline		OC	P	K	Ca	Mg	S	Zn	B	Fe	Cu	Mn
Aul	100	100	0	0	100	64	76	18	0	0	19	28	15	0	0	0
Derabish	140	99	1	0	100	33	9	36	2	9	25	6	90	0	0	0
Garadpur	100	92	8	0	100	57	9	46	0	0	71	59	85	0	0	0
Kendrapada	100	91	7	2	98	18	54	23	0	1	45	26	51	0	0	0
Mahakalapada	200	100	0	0	96	10	47	6	0	0	28	4	4	0	0	0
Marshaghai	100	99	1	0	100	37	45	41	3	4	67	48	80	0	0	0
Pattamundai	100	99	1	0	100	18	53	4	0	0	60	10	31	0	0	0
Rajanagar	220	99	1	0	98	23	51	0	0	0	24	13	0	0	0	0
Rajkanika	90	100	0	0	100	7	32	0	0	0	16	6	19	0	0	0

*EC = Electrical Conductivity.

**OC = Organic Carbon, P = Phosphorous, K= Potassium, Ca= Calcium, Mg = Magnesium, S = Sulfur, Zn = Zinc, B = Boron, Fe = Iron, Cu = Copper and Mn = Manganese.

Annexure 19. Block-level deficiency of major and micronutrients and soil condition in Kendujhar district.

Block	No of samples	Fields under various pH conditions (%)			Fields under normal EC* conditions (%)	Fields with low soil C levels and nutrient deficiencies (%)**										
		Acidic	Neutral	Alkaline		OC	P	K	Ca	Mg	S	Zn	B	Fe	Cu	Mn
Sadar	100	77	10	12	100	45	52	28	15	41	62	54	87	4	0	8
Anandapur	120	89	10	1	100	34	56	43	3	18	59	53	85	0	3	2
Banspal	150	97	3	0	100	12	66	10	3	13	81	59	85	1	1	0
Champua	120	97	2	2	100	49	70	33	32	66	64	57	91	1	3	0
Ghasipura	120	80	19	1	100	63	57	17	12	19	58	39	83	1	1	0
Ghatagaon	110	95	5	1	100	65	82	45	32	63	74	63	94	0	3	5
Harichandanur	200	96	5	0	100	39	76	40	13	40	69	59	90	1	2	2
Hatadihi	150	96	4	0	100	71	67	51	16	40	81	53	91	2	5	5
Jhumpura	120	91	9	0	100	65	63	26	43	77	73	59	91	3	25	0
Joda	50	94	6	0	100	22	66	12	10	22	60	38	82	2	2	0
Patna	100	94	6	0	100	68	74	57	28	74	77	73	98	0	3	4
Saharpada	100	98	0	2	100	41	92	65	22	63	92	84	100	0	1	3
Telkoi	100	97	3	0	100	44	84	26	11	25	78	39	96	0	0	0

*EC = Electrical Conductivity.

**OC = Organic Carbon, P = Phosphorous, K= Potassium, Ca= Calcium, Mg = Magnesium, S = Sulfur, Zn = Zinc, B = Boron, Fe = Iron, Cu = Copper and Mn = Manganese.

Annexure 20. Block-level deficiency of major and micronutrients and soil condition in Khorda district.

Block	No of samples	Fields under various pH conditions (%)			Fields under normal EC* conditions (%)	Fields with low soil C levels and nutrient deficiencies (%)**										
		Acidic	Neutral	Alkaline		OC	P	K	Ca	Mg	S	Zn	B	Fe	Cu	Mn
Balianta	100	91	7	2	100	69	16	34	0	14	62	25	97	0	0	0
Balipatna	120	97	3	1	100	35	14	25	3	10	57	33	70	0	1	1
Banapur	150	98	2	0	100	91	11	83	13	15	88	47	95	0	1	6
Begunia	150	93	3	4	100	41	59	45	33	48	63	13	93	0	0	9
Bhubaneswar	100	89	10	1	100	45	33	7	19	36	42	24	82	0	0	0
Bolagarh	200	99	1	0	100	95	95	11	1	4	95	10	99	0	0	0
Chilika	130	88	8	4	100	32	63	28	8	24	35	39	48	0	0	2
Jatni	100	98	2	0	100	65	61	43	10	55	45	11	67	0	0	0
Khorda	100	81	14	5	100	66	71	53	15	40	63	21	79	0	0	3
Tangi	150	84	16	0	100	58	54	53	25	44	68	35	83	0	0	3

*EC = Electrical Conductivity.

**OC = Organic Carbon, P = Phosphorous, K= Potassium, Ca= Calcium, Mg = Magnesium, S = Sulfur, Zn = Zinc, B = Boron, Fe = Iron, Cu = Copper and Mn = Manganese.

Annexure 21. Block-level deficiency of major and micronutrients and soil condition in Koraput district.

Block	No of samples	Fields under various pH conditions (%)			Fields under normal EC* conditions (%)	Fields with low soil C levels and nutrient deficiencies (%)**										
		Acidic	Neutral	Alkaline		OC	P	K	Ca	Mg	S	Zn	B	Fe	Cu	Mn
Koraput	140	98	2	0	100	21	42	15	2	16	91	36	87	1	1	0
Kotpad	210	99	1	0	100	22	61	24	10	43	93	59	94	0	1	0
Kundura	100	100	0	0	100	28	50	28	20	69	78	58	89	0	0	0
Lamtaput	189	97	3	1	100	13	37	5	21	51	85	44	78	0	2	0
Laxmipur	100	60	34	6	100	8	6	0	0	17	48	3	41	2	0	0
Nandapur	450	99	1	0	100	27	58	6	18	50	92	51	78	0	1	0
Pattangi	100	98	2	0	100	37	19	1	3	20	81	41	58	0	3	0
Semliguda	100	98	2	0	100	38	37	3	24	65	92	58	80	0	0	0
Borigumma	220	100	0	0	100	26	47	27	14	44	92	60	89	0	1	0
Dasamantpur	60	97	3	0	100	20	32	8	20	53	97	63	97	0	0	0
Joypore	100	100	0	0	100	4	72	24	6	39	89	32	93	1	0	0

*EC = Electrical Conductivity.

**OC = Organic Carbon, P = Phosphorous, K= Potassium, Ca= Calcium, Mg = Magnesium, S = Sulfur, Zn = Zinc, B = Boron, Fe = Iron, Cu = Copper and Mn = Manganese.

Annexure 22. Block-level deficiency of major and micronutrients and soil condition in Malkangiri district.

Block	No of samples	Fields under various pH conditions (%)			Fields under normal EC* conditions (%)	Fields with low soil C levels and nutrient deficiencies (%)**										
		Acidic	Neutral	Alkaline		OC	P	K	Ca	Mg	S	Zn	B	Fe	Cu	Mn
Kalimela	129	76	22	1	100	43	60	36	8	19	51	48	97	1	2	2
Khairiput	100	97	2	1	100	27	63	16	11	31	64	40	98	1	7	3
Korkunda	148	95	4	1	100	34	61	30	2	26	39	38	97	1	3	1
Mathili	200	95	5	1	100	49	70	50	11	57	55	57	88	1	2	2
Podia	60	88	10	2	100	32	73	15	13	37	72	53	85	0	0	0
Chitrakonda	300	39	34	27	100	31	83	28	1	9	23	33	45	0	1	0

*EC = Electrical Conductivity.

**OC = Organic Carbon, P = Phosphorous, K= Potassium, Ca= Calcium, Mg = Magnesium, S = Sulfur, Zn = Zinc, B = Boron, Fe = Iron, Cu = Copper and Mn = Manganese.

Annexure 23. Block-level deficiency of major and micronutrients and soil condition in Mayurbhanj district.

Block	No of samples	Fields under various pH conditions (%)			Fields under normal EC* conditions (%)	Fields with low soil C levels and nutrient deficiencies (%)**										
		Acidic	Neutral	Alkaline		OC	P	K	Ca	Mg	S	Zn	B	Fe	Cu	Mn
Badasahi	200	99	1	0	100	47	50	44	5	24	40	25	81	0	1	1
Bahalda	90	97	3	0	100	49	76	61	20	46	60	47	96	0	4	9
Bangriposi	200	92	7	2	99	33	72	17	4	13	38	34	82	2	1	1
Baripada	100	100	0	0	100	64	85	68	54	69	79	33	97	0	0	6
Betnati	250	100	0	0	100	71	84	82	45	79	80	46	98	0	3	1
Bijatala	100	99	1	0	100	29	64	36	17	29	72	34	89	0	0	0
Bisoi	150	98	2	0	100	29	69	36	29	40	71	54	89	0	2	0
Gopobandhunagar	100	100	0	0	100	39	70	41	15	62	77	33	96	0	1	0
Jamda	50	100	0	0	100	52	92	50	24	38	80	62	96	0	2	6
Jashipur	200	100	1	0	100	53	88	32	18	44	88	64	100	1	4	3
Kaptipada	100	100	0	0	100	32	84	49	35	49	80	49	98	0	0	0
Karanjia	140	99	1	0	100	36	81	48	23	69	85	42	98	0	2	0
Khunta	100	98	2	0	99	15	86	31	24	45	81	17	97	0	0	0
Kuliana	200	99	1	0	100	57	86	54	37	51	75	39	84	0	1	2
Kusumi	99	96	4	0	100	39	84	36	14	24	76	32	90	0	0	0
Morada	150	99	1	0	100	70	75	72	45	67	65	47	97	0	1	5
Rairangpur	90	100	0	0	99	36	87	61	32	58	77	46	94	0	0	0
Raruan	100	100	0	0	100	27	66	25	18	35	46	30	83	1	2	0
Rasgobindopur	150	99	1	0	100	31	57	68	41	71	51	32	88	0	0	1
Samakhunta	99	97	3	0	100	41	81	56	13	34	76	37	97	2	0	1
Saraskana	150	97	3	0	100	47	77	42	9	45	53	53	97	0	0	1
Sukruli	79	100	0	0	100	41	62	44	28	68	70	29	97	0	0	0
Suliapada	170	75	25	1	100	45	56	37	26	59	48	23	87	9	0	0
Thakurmunda	150	98	2	0	100	47	68	31	35	69	69	33	87	1	1	1
Tiring	50	100	0	0	100	56	78	48	42	56	46	36	94	0	0	10
Udala	50	100	0	0	100	56	72	28	30	54	72	40	84	0	0	0

*EC = Electrical Conductivity.

**OC = Organic Carbon, P = Phosphorous, K= Potassium, Ca= Calcium, Mg = Magnesium, S = Sulfur, Zn = Zinc, B = Boron, Fe = Iron, Cu = Copper and Mn = Manganese.

Annexure 24. Block-level deficiency of major and micronutrients and soil condition in for Nabarangpur district.

Block	No of samples	Fields under various pH conditions (%)			Fields under normal EC* conditions (%)	Fields with low soil C levels and nutrient deficiencies (%)**										
		Acidic	Neutral	Alkaline		OC	P	K	Ca	Mg	S	Zn	B	Fe	Cu	Mn
Chandahandi	100	72	20	8	100	30	67	5	2	12	25	65	83	1	2	7
Dabugam	148	95	5	0	100	63	80	31	11	35	82	71	99	0	0	0
Jharigan	101	95	5	0	100	27	69	22	4	26	76	63	93	0	0	0
Kosagumunda	119	99	1	0	100	34	66	18	19	50	76	58	97	0	0	0
Nabarangpur	20	65	35	0	100	10	60	30	0	0	60	75	100	0	0	0
Nabarangpur	70	90	10	0	100	30	57	23	4	21	79	44	100	0	0	0
Nandahandi	88	98	2	0	100	24	55	25	17	41	66	38	94	0	3	2
Papadahandi	100	99	1	0	100	24	43	23	7	28	58	45	90	0	1	0
Raighar	161	96	2	2	100	54	75	30	21	58	84	86	99	1	1	31
Sanmasigan	10	90	10	0	100	0	70	30	0	0	50	20	100	0	0	0
Tentuli Khunti	198	97	3	0	100	32	53	10	7	29	68	48	95	0	0	0
Umarkote	98	99	0	1	100	58	35	23	27	66	82	59	96	1	9	0

*EC = Electrical Conductivity.

**OC = Organic Carbon, P = Phosphorous, K= Potassium, Ca= Calcium, Mg = Magnesium, S = Sulfur, Zn = Zinc, B = Boron, Fe = Iron, Cu = Copper and Mn = Manganese.

Annexure 25. Block-level deficiency of major and micronutrients and soil condition in Nayagarh district.

Block	No of samples	Fields under various pH conditions (%)			Fields under normal EC* conditions (%)	Fields with low soil C levels and nutrient deficiencies (%)**										
		Acidic	Neutral	Alkaline		OC	P	K	Ca	Mg	S	Zn	B	Fe	Cu	Mn
Bhapur	100	92	5	3	100	66	58	35	11	20	53	59	90	0	0	0
Dasapalla	200	63	29	9	100	49	32	15	2	10	40	53	73	3	1	1
Gania	100	76	17	6	100	33	50	10	0	6	53	51	89	0	0	2
Khandapada	120	93	7	0	100	55	58	18	7	27	52	31	92	0	0	0
Nayagarh	100	66	23	10	100	57	35	23	0	1	42	46	75	4	0	3
Nuagaon	120	62	32	7	100	41	40	18	3	9	40	35	75	0	1	1
Odagaon	150	72	18	10	100	53	41	18	0	0	45	41	73	0	0	1
Ranpur	150	79	15	5	100	77	37	57	9	27	61	23	88	0	0	3

*EC = Electrical Conductivity.

**OC = Organic Carbon, P = Phosphorous, K= Potassium, Ca= Calcium, Mg = Magnesium, S = Sulfur, Zn = Zinc, B = Boron, Fe = Iron, Cu = Copper and Mn = Manganese.

Annexure 26. Block-level deficiency of major and micronutrients and soil condition in Nuapada district.

Block	No of samples	Fields under various pH conditions (%)			Fields under normal EC* conditions (%)	Fields with low soil C levels and nutrient deficiencies (%)**										
		Acidic	Neutral	Alkaline		OC	P	K	Ca	Mg	S	Zn	B	Fe	Cu	Mn
Boden	100	42	33	25	100	24	80	0	0	3	31	71	91	2	1	3
Khariar	100	28	28	44	100	18	56	1	0	2	15	61	69	1	1	13
Komna	150	41	40	19	100	29	63	1	1	1	25	67	81	3	0	7
Nuapada	147	60	27	13	100	21	69	3	2	10	18	84	89	1	3	12
Sinapali	150	47	37	16	100	20	58	0	0	2	43	74	71	1	0	4

*EC = Electrical Conductivity.

**OC = Organic Carbon, P = Phosphorous, K= Potassium, Ca= Calcium, Mg = Magnesium, S = Sulfur, Zn = Zinc, B = Boron, Fe = Iron, Cu = Copper and Mn = Manganese.

Annexure 27. Block-level deficiency of major and micronutrients and soil condition in Puri district.

Block	No of samples	Fields under various pH conditions (%)			Fields under normal EC* conditions (%)	Fields with low soil C levels and nutrient deficiencies (%)**										
		Acidic	Neutral	Alkaline		OC	P	K	Ca	Mg	S	Zn	B	Fe	Cu	Mn
Astarang	100	94	6	0	99	63	29	29	3	3	46	12	50	0	0	1
Brahmagiri	150	96	3	1	100	49	29	41	29	33	45	36	64	1	7	19
Delang	90	89	10	1	100	33	36	41	2	13	42	17	69	0	0	3
Gop	150	98	2	0	100	32	26	22	1	1	73	28	37	0	0	1
Kakatpur	100	98	0	2	100	58	39	43	0	1	79	45	84	0	0	0
Kanas	150	95	5	0	97	31	47	7	0	3	31	13	35	0	0	0
Krushnaprasad	100	90	9	1	100	95	19	74	80	89	72	45	97	0	40	62
Nimapada	180	98	2	0	100	18	20	16	0	0	43	33	56	0	0	0
Pipili	150	97	3	0	100	43	11	49	3	15	40	30	83	0	0	1
Purisadar	100	96	1	3	100	49	37	51	7	14	43	48	64	0	1	2
Satyabadi	150	99	0	1	100	39	29	39	0	5	44	24	73	0	0	0

*EC = Electrical Conductivity.

**OC = Organic Carbon, P = Phosphorous, K= Potassium, Ca= Calcium, Mg = Magnesium, S = Sulfur, Zn = Zinc, B = Boron, Fe = Iron, Cu = Copper and Mn = Manganese.

Annexure 28. Block-level deficiency of major and micronutrients and soil condition in Rayagada district.

Block	No of samples	Fields under various pH conditions (%)			Fields under normal EC* conditions (%)	Fields with low soil C levels and nutrient deficiencies (%)**										
		Acidic	Neutral	Alkaline		OC	P	K	Ca	Mg	S	Zn	B	Fe	Cu	Mn
Bissamcuttack	130	90	8	2	100	42	42	3	8	46	51	25	64	1	2	1
Chandrapur	100	91	8	1	100	37	53	12	3	21	54	36	91	0	1	1
Gudari	100	72	21	7	100	47	34	8	6	24	44	50	72	7	4	2
Kalyansingpur	130	91	8	2	100	55	15	5	4	38	54	19	85	2	2	0
Kolnara	100	94	4	2	100	68	8	2	7	30	32	16	89	0	0	0
Muniguda	200	89	11	1	100	62	18	6	10	41	50	22	86	1	7	0
Padmapur	100	49	38	13	100	80	21	2	5	23	44	59	77	18	1	2
Rayagada	180	74	21	6	100	35	14	0	9	32	32	15	62	4	1	3
Kashipur	200	100	0	0	100	42	62	8	5	28	99	71	57	8	1	0
Gunpur	190	81	18	2	100	57	53	13	3	26	62	50	73	4	2	4

*EC = Electrical Conductivity.

**OC = Organic Carbon, P = Phosphorous, K= Potassium, Ca= Calcium, Mg = Magnesium, S = Sulfur, Zn = Zinc, B = Boron, Fe = Iron, Cu = Copper and Mn = Manganese.

Annexure 29. Block-level deficiency of major and micronutrients and soil condition in Sambalpur district.

Block	No of samples	Fields under various pH conditions (%)			Fields under normal EC* conditions (%)	Fields with low soil C levels and nutrient deficiencies (%)**										
		Acidic	Neutral	Alkaline		OC	P	K	Ca	Mg	S	Zn	B	Fe	Cu	Mn
Bamara	150	87	9	3	97	57	56	15	12	30	40	41	84	7	3	3
Dhankauda	100	99	1	0	100	33	44	48	20	59	27	31	96	1	1	9
Jamankira	250	94	4	2	98	42	62	14	10	29	48	45	96	3	2	1
Jujumura	100	84	2	14	100	35	59	17	8	40	43	46	89	7	0	12
Kuchinda	100	92	7	1	100	53	32	9	17	48	61	58	91	2	1	3
Maneswara	100	87	9	4	100	48	43	9	2	17	36	56	98	0	1	1
Nakatideula	150	90	7	3	100	25	53	23	19	34	47	31	93	0	0	1
Rairakhola	150	76	17	7	100	17	61	15	9	26	41	25	95	1	3	1
Rengali	70	93	6	1	100	56	56	26	20	49	60	39	84	0	3	1

*EC = Electrical Conductivity.

**OC = Organic Carbon, P = Phosphorous, K= Potassium, Ca= Calcium, Mg = Magnesium, S = Sulfur, Zn = Zinc, B = Boron, Fe = Iron, Cu = Copper and Mn = Manganese.

Annexure 30. Block-level deficiency of major and micronutrients and soil condition in Subarnapur district.

Block	No of samples	Fields under various pH conditions (%)			Fields under normal EC* conditions (%)	Fields with low soil C levels and nutrient deficiencies (%)**										
		Acidic	Neutral	Alkaline		OC	P	K	Ca	Mg	S	Zn	B	Fe	Cu	Mn
Binka	90	97	2	1	100	52	57	43	14	48	17	28	99	0	12	0
Birmaharajpur	130	67	22	11	100	33	56	16	1	16	28	63	85	5	0	3
Dunguripali	100	74	19	7	100	22	56	40	3	39	6	45	93	2	0	3
Subarnapur	120	68	24	8	100	40	50	25	8	34	34	72	92	1	2	2
Tarbha	140	38	37	25	100	36	74	16	1	4	28	88	95	2	1	7
Ullunda	200	73	21	7	100	34	47	15	8	24	27	69	84	1	1	5

*EC = Electrical Conductivity.

**OC = Organic Carbon, P = Phosphorous, K= Potassium, Ca= Calcium, Mg = Magnesium, S = Sulfur, Zn = Zinc, B = Boron, Fe = Iron, Cu = Copper and Mn = Manganese.

Annexure 31. Block-level deficiency of major and micronutrients and soil condition in Sundargarh district.

Block	No of samples	Fields under various pH conditions (%)			Fields undernormal EC* conditions (%)	Fields with low soil C levels and nutrient deficiencies (%)**										
		Acidic	Neutral	Alkaline		OC	P	K	Ca	Mg	S	Zn	B	Fe	Cu	Mn
Badagaon	100	98	2	0	70	61	53	18	15	34	55	61	98	0	4	1
Balisankara	100	79	14	7	100	46	57	9	8	43	39	51	90	2	6	4
Bonigarh	100	100	0	0	100	38	72	17	9	21	35	20	86	0	0	0
Birsa	300	92	7	0	100	53	81	25	8	25	50	38	96	0	1	2
Hemgir	240	95	5	0	100	38	79	27	21	48	55	43	97	0	3	2
Koira	10	100	0	0	100	10	70	20	60	60	70	60	70	0	0	0
Kuarmunda	250	97	3	0	100	70	90	17	41	65	41	62	98	4	31	0
Kutra	190	97	3	0	100	35	72	11	19	44	44	34	97	3	4	0
Gurundia	10	90	10	0	100	90	90	0	0	10	90	90	100	10	0	0
Lahunipara	200	100	0	0	100	25	83	16	5	31	77	20	99	0	0	0
Lathikata	100	92	7	1	100	40	80	17	15	39	41	40	95	0	1	2
Lephripara	130	90	6	2	100	51	65	16	2	20	28	38	98	0	1	2
Rajangpur	100	87	12	1	100	54	81	14	5	29	28	40	93	3	2	3
Subdega	100	98	1	1	100	61	63	14	10	28	50	45	97	1	3	1
Sadar	100	100	0	0	100	65	57	32	13	43	37	39	96	0	1	1
Tangarpalli	100	97	3	0	100	41	57	20	5	24	16	19	90	1	0	0

*EC = Electrical Conductivity.

**OC = Organic Carbon, P = Phosphorous, K= Potassium, Ca= Calcium, Mg = Magnesium, S = Sulfur, Zn = Zinc, B = Boron, Fe = Iron, Cu = Copper and Mn = Manganese.

Chapter 4

Management of Acidic Soils

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Introduction

Soil acidity is a serious constraint to crop production in many regions of the world including India. Acidic soils in India are mainly prevalent in the humid Southwestern, Northeastern and Himalayan regions (Maji et al. 2008). They are particularly acute in the humid tropical regions that have been subjected to severe weathering. In India, about 48 m ha out of 142 m ha of arable land are affected by acidity, of which 25 m ha have pH below 5.5 and 23 m ha have pH between 5.6 and 6.5 (Mandal 1997). Strongly acidic and moderately acidic soils cover 6.24 m ha (1.9%) and 24.41 m ha (7.4%), respectively of the country's total geographic area (Maji et al. 2012). In the Northeastern region, approximately 95% of the soils are acidic and nearly 65% have strong acidity with pH below 5.5 (Sharma and Singh 2002). Acidic soils of Odisha account for 70% of its total geographical area (Jena 2008). A similar finding was reported in Odisha by Nanda et al. (2008) based on the analyses of 1,219,000 soil samples. A recent study conducted by ICRISAT found that of the 40,265 soil samples analysed, more than 80% were acidic in nature (see Chapter 3).

Effects of soil acidity

The major limiting factors associated with acidic soils (Table 4.1.) are toxic effects, nutrient imbalance and reduced microbial activity. Soil acidity causes toxicity of aluminium (Al) and manganese (Mn) and reduces the availability of nutrients such as calcium, magnesium, phosphorus, nitrogen, boron and molybdenum. It also retards biological activities in the rhizosphere, especially the symbiotic/or mutualistic association of plants with beneficial fauna and flora (Thakuria et al. 2016). These factors directly and indirectly affect plant growth. Other major constraints associated with acidic soils include severe water stress due to restricted root growth in the subsurface horizon (Adams 1984). Together, these severely limit the scope of increasing crop productivity. Aluminium toxicity and the associated deficiency of phosphorus are major constraints to crop production on 67% of the total acidic soils in the country (Eswaran et al. 1997).

Table 4.1. Classification of soils based on pH (Sarkar 2015).

Category	pH range
Extremely acidic	<4.5
Very strongly acidic	4.5-5.0
Strongly acidic	5.1-5.5
Moderately acidic	5.6-6.0
Slightly acidic	6.1-6.5
Neutral	6.6-7.3
Slightly alkaline	7.4-7.8
Moderately alkaline	7.9-8.4
Strongly alkaline	8.5-9.0
Very strongly alkaline	> 9.0

Soil classification based on pH

The causes of soil acidity include acidic parent materials such as granite, gneiss, sandstone; leaching of basic cations (Ca, Na, K and Mg), sesquioxides and humus, accumulation of organic matter, carbonic and other organic acids; soil forming processes like lateralisation and podzolisation; oxidation of sulfur and the application of acid forming inorganic fertilizers.

Acidic soil management

Liming

Amelioration of soil and sub-soil acidity constitutes an important aspect of acidic soil management. Application of lime and/or alternative liming material along with other management practices are needed to address soil acidity (Tables 4.2 and 4.3). Apart from increasing yield, application of lime enhances the efficiency of applied fertilizers, improves the effectiveness of some herbicides, protects the environment and increases the net profit of farmers (Prochnow 2014).

Benefits of liming

- Reduces soil acidity and improves soil pH, base saturation and CEC
- Increases nutrient availability
- Changes insoluble soil complexes of P and S to more plant available forms
- Improves biological activity
- Improves nitrogen fixing by legumes
- Improves soil physical structure
- Reduces Fe, Al and Mn toxicities
- Improves the effectiveness of certain herbicides
- Reduces fungal diseases
- Increases crop yields.

Table 4.2. Calcium carbonate equivalent (CCE) values of some important liming materials.

Liming materials	Calcium carbonate equivalent (%)*
Calcium oxide	179
Magnesium oxide	250
Calcium hydroxide	136
Magnesium carbonate	119
Dolomite	109
Calcium carbonate	100
Basic slag	86
Paper mill sludge	80

* Calcium carbonate equivalent is the acid-neutralizing capacity of the material compared to pure calcium carbonate expressed as a weight percentage of $CaCO_3$ (Das 2014).

Liming material with source	Effective neutralizing value*/ Calcium carbonate equivalent (%)	Ca (%)
Ballarpur Paper Mill Sludge (PMS)	60.8-84.2 (64.9)**	20.2-29.0 (21.7)
Rayagada PMS	55.4-92.0 (73.9)	20.8-46.56 (30.5)
Brajarajnagar PMS	66.6-84.1 (78.9)	27.0-50.25 (34.6)
Jeypore PMS	51.8-86.6 (71.0)	20.6-33.0 (27.0)
Emami PMS, Balasore	37.4	12.2
Press mud, Aska Sugar Factory	2.8	4.5
Dolomitic limestone	192.05	55.0
Chilika liming material (shell)	190.15	47.5

Table 4.3. Characterization of locally available liming materials in Odisha.

Source: Jena (2008)

* Effective neutralizing value (ENV) is a quality index used to express the effectiveness of liming material in neutralizing soil acidity. The quality index is based on both purity and fineness.

** Figures in parenthesis are mean values.

Harmful effects of over-liming

One of the most detrimental effects of over-liming is the alteration of the physical properties, rather than the chemical properties in tropical soils. Soil permeability is also known to be affected by over-liming. High infiltration rates and consequent rapid leaching of bases from tropical soils are attributed to highly unstable soil structure and increased binding tendency of ferrous and aluminum oxides in soil particles. Over-liming destabilizes the soil structure, which in turn causes soil aggregates to break apart resulting in reduced permeability and inadequate drainage. The addition of lime of either calcium or magnesium to soil increases the number of small aggregates at the expense of larger ones.

Pulp and paper mill effluents

Huge quantities of effluents are generated from pulp and paper, tannery and textile industries that could be used in managing acid soils. Paper Mill Sludge (PMS) has been tested for its suitability and found to be a good and cheap source compared to calcite and dolomite. Table 4.4. gives an estimate of available PMS in Odisha.

Lime sludge is a solid waste produced while converting wood/bamboo chips into pulp in the paper industry. Its major component is $CaCO_3$; it contains low levels of potentially toxic heavy metals and can be a cheap source of amelioration of soil acidity.

Integrated Nutrient Management (INM)

Integrated Nutrient Management constitutes the use of lime, organic manure and inorganic fertilizers, and is often recommended to increase crop productivity in acidic soils. Besides better soil aggregation, narrow

Table 4.4. Annual availability of PMS in Odisha.

Paper mill	Annual production (m t)
Emami Paper Mill, Balasore	25,000
JK Paper Mill, Rayagada	30,000
Sewa Paper Mill, Koraput	2,500

Source: Jena (2008).

fungal:bacterial biomass ratio, greater number of earthworm casts and greater diversity in bacterial community are some significant positive aspects of INM in acidic soils.

Phospho-gypsum (PG) or gypsum

Chemically, gypsum ($CaSO_4.2H_2O$) is a neutral salt with no direct effect on soil pH. However, many researchers have shown that phospho-gypsum, a by-product in the production of phosphoric acid from phosphate ore and sulfuric acid, can ameliorate sub-soil acidity and hasten root development. This is very relevant in rainfed ecosystems where the absorption of water and nutrients is limited due to poor development of the root system.

Growing acid-tolerant crops

Aluminium toxicity limits crop production in acidic soils, to which soil liming is the answer. However, considering the huge quantities of lime and associated costs involved in amelioration of these soils, growing acid-tolerant crops and cultivars might be a viable alternative. Blueberries, potatoes and watermelons tend to be more acid tolerant than crops like corn, soybean, wheat, alfalfa and clover. There is considerable variability in Al tolerance among plant species, which has enabled breeders to develop Al-tolerant cultivars and study the physiology and biochemistry of Al tolerance in germplasm. Wheat has proven to be a useful candidate in this respect, with up to 10-fold difference in Al tolerance among its genotypes compared to other cereals (Prochnow, 2014). Paddy is a good choice because flooding neutralizes the acidity and associated negative effects where water is abundantly available.

Agroforestry systems such as multi-storey cropping systems can also reduce erosivity of raindrops and leachability of nutrients. The system's ability to reduce soil acidity depends on the tree species and the structure of the agroforestry system. Baggie et al. (2000) investigated the potential of organic residues from nitrogen fixing trees such as *Albizia zygia* and *Gliricidia sepium* to ameliorate acid infertile rice soils. It was revealed that after four weeks of incubation, *A. zygia* and *G. sepium* increased the pH of the soil from 4.4 to 5.1 and 5.3, respectively as these species exude basic cations into the rhizosphere.

Organic manure as an amendment

Both logistic and economic reasons make it impractical for resource poor farmers to apply high quantities of lime in acidic soils. This has led to exploring alternatives. Organic materials of plant and animal origin have been known to improve the fertility, structure and biological properties of soil, in addition to reducing soil acidity or associated Al saturation. The magnitude of soil pH increase depends on the type of organic manure, its rate of application and buffering capacity of the soil. It was found that the application of 20 t/ha and 40–50 t/ha of organic residue increased soil pH by 0.2–0.6 and 0.8–1.5 units, respectively (Noble et al. 1996). Application of organic manure to acidic soils has a direct effect on soil organic matter content, amelioration of Al toxicity and reduction in soil acidity. This is mainly attributed to the complexation process in the soil (Wong and Swift 2003).

It was also demonstrated that pig stay manure was more effective than $CaCO_3$ in ameliorating Al toxicity in red acidic soils. Addition of green manure and animal waste to acidic soils reduced Al toxicity and increased crop yields (Hue 1992). Other effects may include the enrichment of soil fertility, improving soil physical characteristics and augmenting microbial activities.

Similarly, using biogas slurry, crop residues and organic materials like biochar could be the right choices to manage acidic soils. Pyrolytic biochar can be used as a soil amendment to improve soil fertility and reduce soil acidity (Steiner et al. 2007; Chan et al. 2008). The ameliorative effects of direct incorporation of plant materials into soils cannot last long, as they are rapidly decomposed by microorganisms (Xu et al. 2006). It was indicated that biochar is recalcitrant and might persist for hundreds of years in soils (Rebecca 2007). Natural coal and coal extracts have also been shown to ameliorate acidic soils and improve root growth (Yazawa et al. 2000).

Rhizosphere management and other approaches

Depending on the pH, clay, organic matter, sesquioxides and phosphorous fixing ability of acidic soils, P applied as water soluble Single Super Phosphate (SSP) is often transformed into aluminium and iron-bound complexes within 24 hours of application and may become unavailable for uptake by plants. Such fixation has been observed to be less in the case of Rock Phosphate (RP) (Bhattacharya and Singh. 1990). Under such circumstances, rhizosphere-based P management might be useful in enhancing phosphorous use efficiency in acidic soils (Kalidas-Singh et al. 2013). This involves synchronization of P mineralization rate in the rhizosphere with P uptake by the plant during various growth phases, minimizing phosphorous fixation in the rhizosphere and increasing tissue phosphorous concentration for better root development during the initial stages of crop growth.

These may be achieved by building up the population of Phosphate Solubilizing Microorganisms (PSM) in the rhizosphere, slow release of P over a long duration through combined application of PSM and RP and root dipping of seedlings in a orthophosphate solution. Phosphate Solubilizing Bacteria (PSB) can dissolve the bound forms of phosphates into available monocalcium phosphate in the soils. This occurs due to exudation of organic acids (e.g., gluconic acid), release of pathogen-suppressing metabolites like siderophores, phytohormones and lytic enzymes, and increase in phosphatases activity in the roots to hydrolyse organic P compounds to improve P acquisition by the plant (Richardson et al. 2009).

Liming the wetted zone or using calcium nitrate as nitrogen source through fertigation could be another best option to manage acidic soils. Fallow time is required for the climax vegetation to accumulate the required nutrients and for associated soil chemical and physical conditions to be established. Seed priming with water and nutrient solutions such as P and Zn is an important strategy to reduce fertiliser requirement, strengthening crop establishment and increasing crop yields (Sekiya and Yano 2010). Since nutrients or nutrient sources are directly applied to seeds, many undesirable interactions between the applied nutrient and the soil matrix (such as fixation of applied P) could be avoided.

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Chapter 5

Developing Soil Nutrient Maps of Odisha using Digital Soil Mapping Techniques

Mukund Patil

Inappropriate use of fertilizer leads to degradation of agricultural land, contamination of water bodies and lowers crop yields. Thus, balanced nutrient management in agriculture is necessary for sustainable crop production. Key to planning and implementing a strategy for balanced nutrient application across the state is knowledge of the nutrient status of the soil. In addition to the results of soil analyses that were shared with individual farmers in the form of soil health cards and wall writings at village/block/district levels, the Bhoochetana project also developed soil nutrient maps to help policymakers and the Department of Agriculture understand the status of nutrients spatially across the state and to aid in framing policies on nutrient subsidy mobilization to address large-scale deficiencies.

Digital soil mapping

Digital Soil Mapping (DSM) or predictive soil mapping provides options to generate information on soil surface properties at high resolution. There are three steps involved in the preparation of digital soil maps: (1) Collection of legacy soil data or field and laboratory measurement of soil properties and the development of base maps from available data, including climate information, land cover, terrain and geological variables; (2) Estimation of soil property using the quantitative relationship between point-wise measured data and spatial maps prepared in step one and (3) Use of estimated soil properties to derive more difficult-to-measure soil properties such as soil water storage, carbon density and phosphorus fixation[1]. Although DSM products have some prediction uncertainties, they provide spatial information at a much higher resolution and at lesser cost.

The methodology adopted to develop soil maps is given in Figure 5.1. The key variables used to develop the model for Odisha's soils were soil type, agro-ecological zones, elevation, precipitation and temperature. The Digital Elevation Model (DEM) of the study area for Odisha state acquired from the Shuttle Radar Topographic Mission (SRTM) with spatial resolution of 90 m was downloaded. The global raster data of WorldClim Bioclimatic variables for WorldClim version 2 was used to extract the bioclimatic variables with respect to point-wise data[2]. These bioclimatic variables were the average for years 1970-2000. The Random Forest (RF) model was used to develop a predictive soil model and maps using Bhoochetana data. While modelling, data was partitioned into 75% points for calibration and 25% points for validation of the model. Calibrated models were used to prepare soil nutrient maps.

Soil nutrient maps

Three types of maps were prepared for a clearer interpretation of results: (1) Soil parameter values at 250 X 250 m resolution (pixel level map); (2) Soil parameter values classified as per fertility indices

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(classified map) and (3) Classified soil parameters aggregated to block level. These three types of maps were prepared to guage pH, electrical conductivity, organic carbon, exchangeable potassium and for available nutrients such as phosphorous, sulfur, boron and zinc. The range of soil parameter values used for classification are presented in Table 5.1.

Table 5.1. Range of soil parameter values for classification.

Parameter	**Value range**	**Classification**
pH	<4.4	Extreme to ultra acidic
	4.5-5.5	Strong to very strong acidic
	5.6-6.5	Slight to moderately acidic
	6.6-7.3	Neutral
	7.4-8.4	Slight to moderately alkaline
	>8.4	Strong to very strong alkaline
Electrical conductivity (dS/m)	<0.8	Normal
	0.8-1.6	Critical to salt sensitive crops
	1.6-2.5	Critical to salt tolerant crops
	>2.5	Injurious to crop
Organic carbon (%)	<0.5	Low
	0.5-0.75	Medium
	>0.75	High
Available phosphorous (mg/kg)	<5	Low
	5-10	Medium
	>10	High
Exchangeable potassium (mg/kg)	<50	Low
	50-100	Medium
	>100	High
Available sulfur (mg/kg)	<10	Deficient
	>=10	Sufficient
Available boron (mg/kg)	<0.58	Deficient
	>=0.58	Sufficient
Available zinc (mg/kg)	<0.75	Deficient
	>=0.75	Sufficient

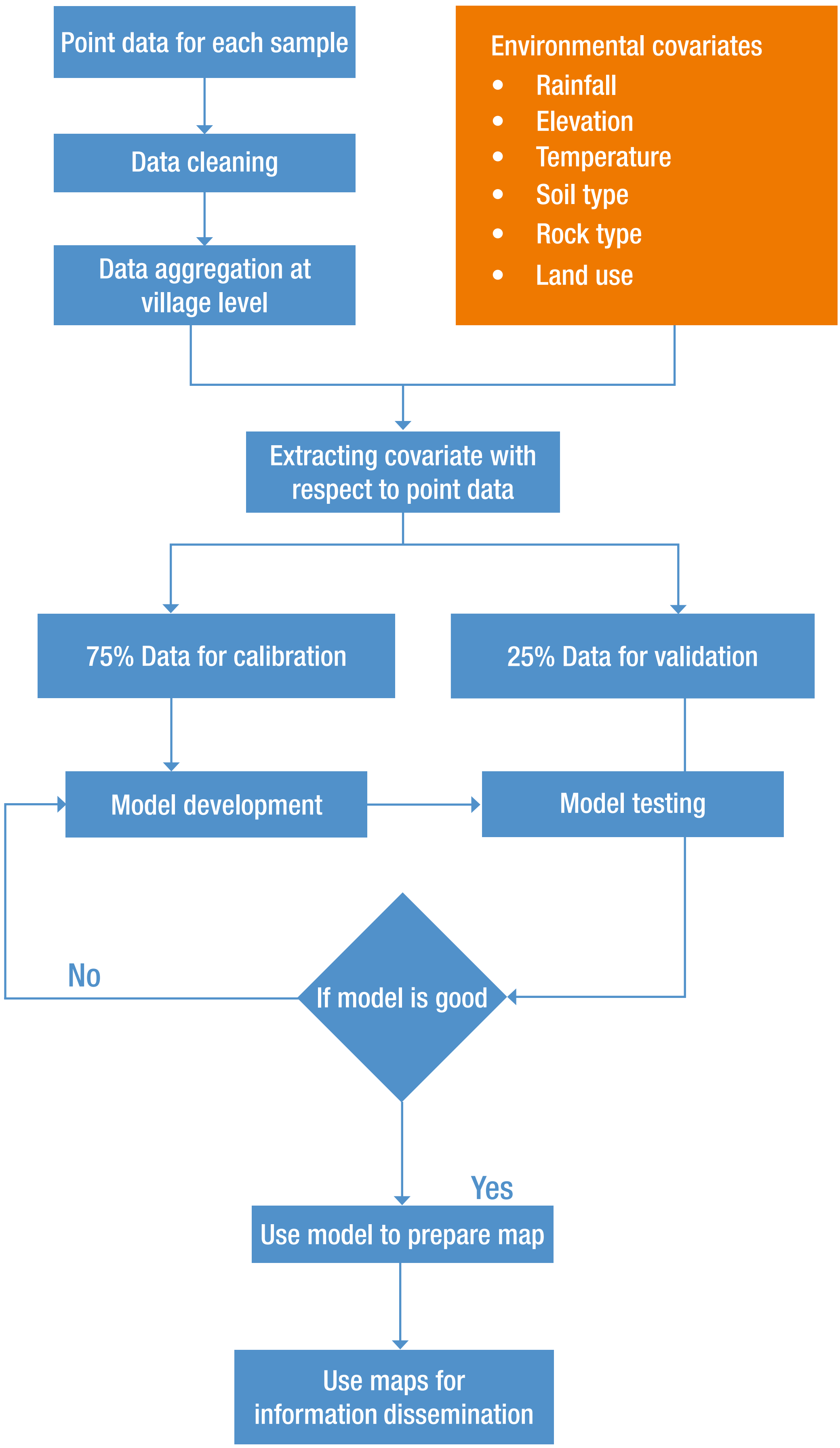


Figure 5.1. Methodology adopted to develop soil nutrient maps for Odisha state.

State level maps | pH

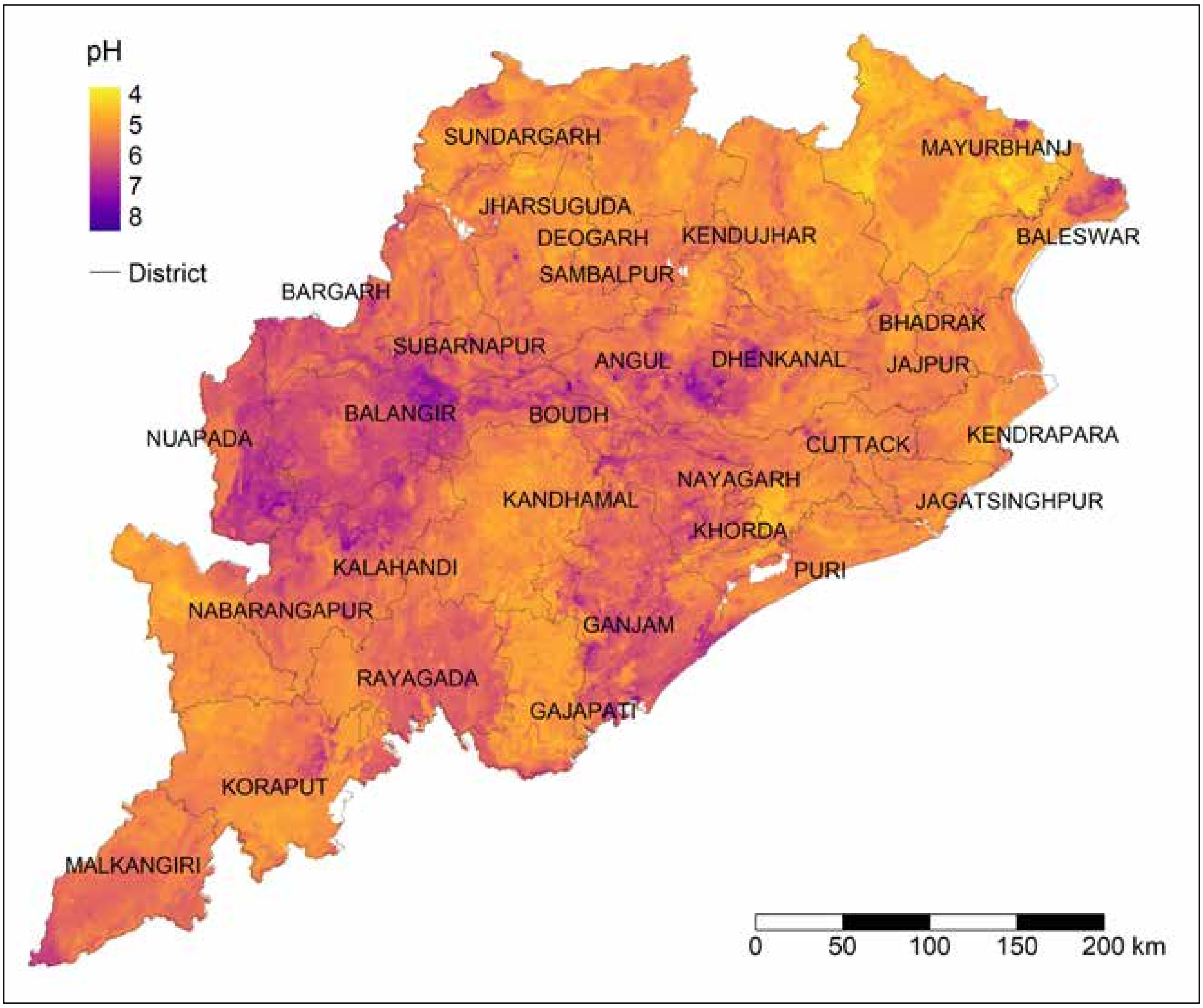


Figure 5.2. State level soil pH.

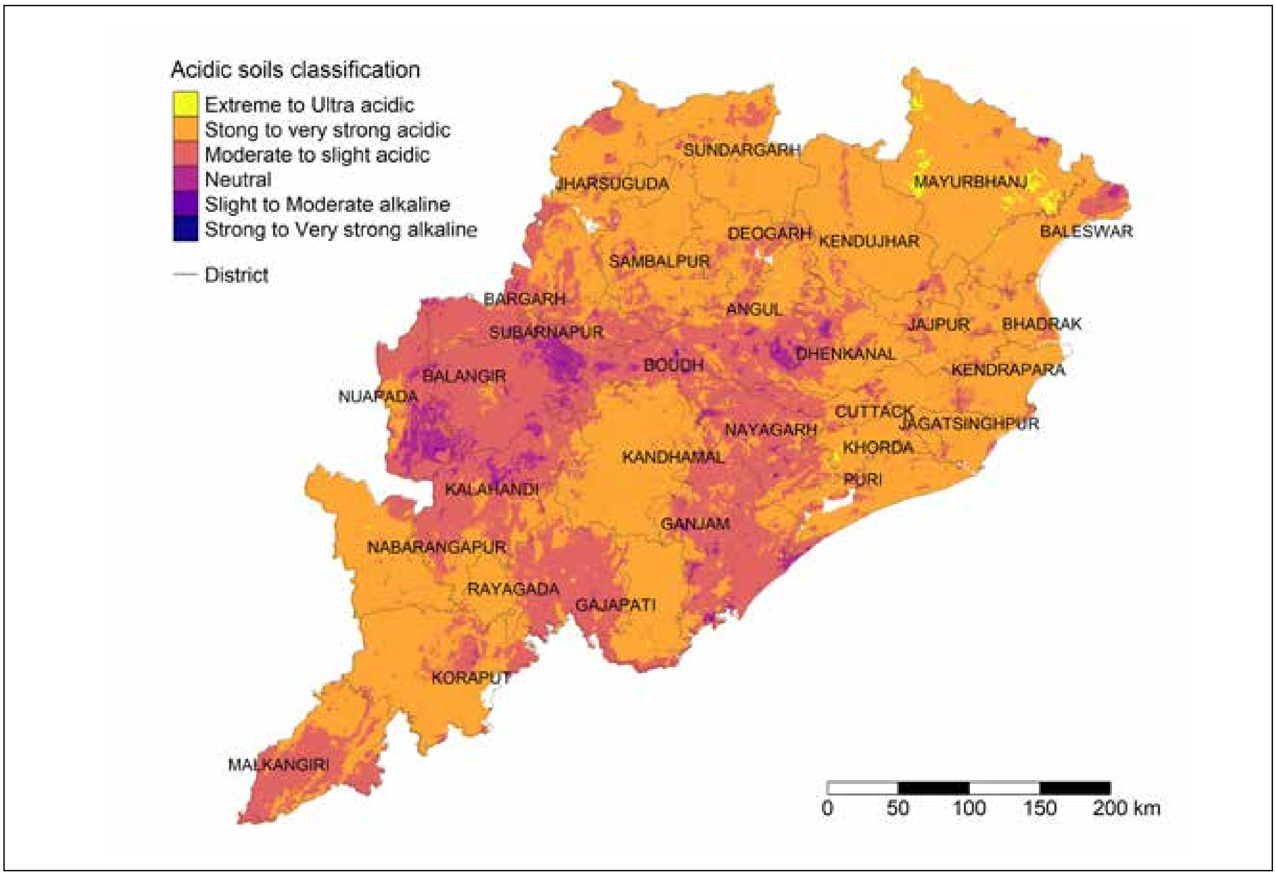


Figure 5.3. Acidic soil classification based on soil pH.

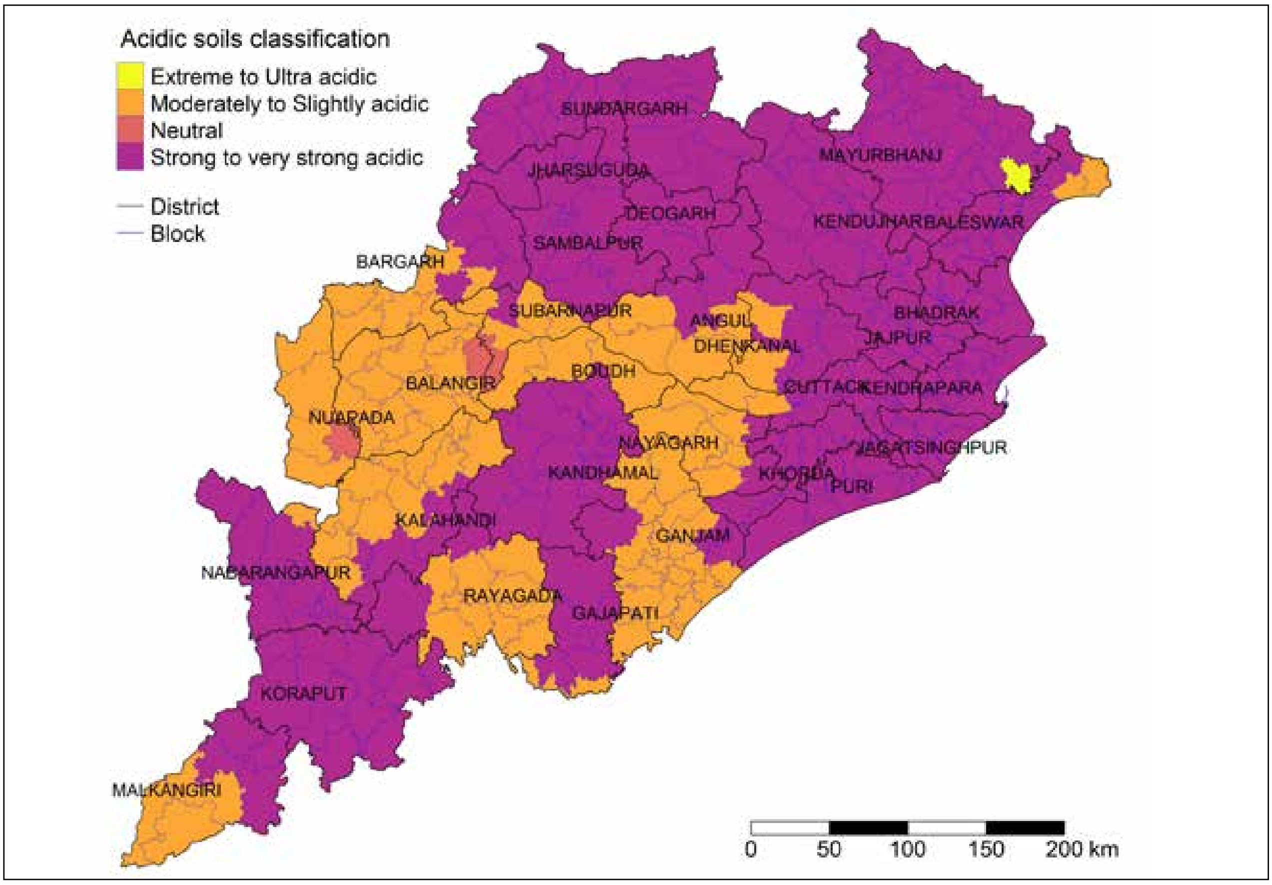


Figure 5.4. Acidic soil classification using aggregated values at block level.

Electrical conductivity

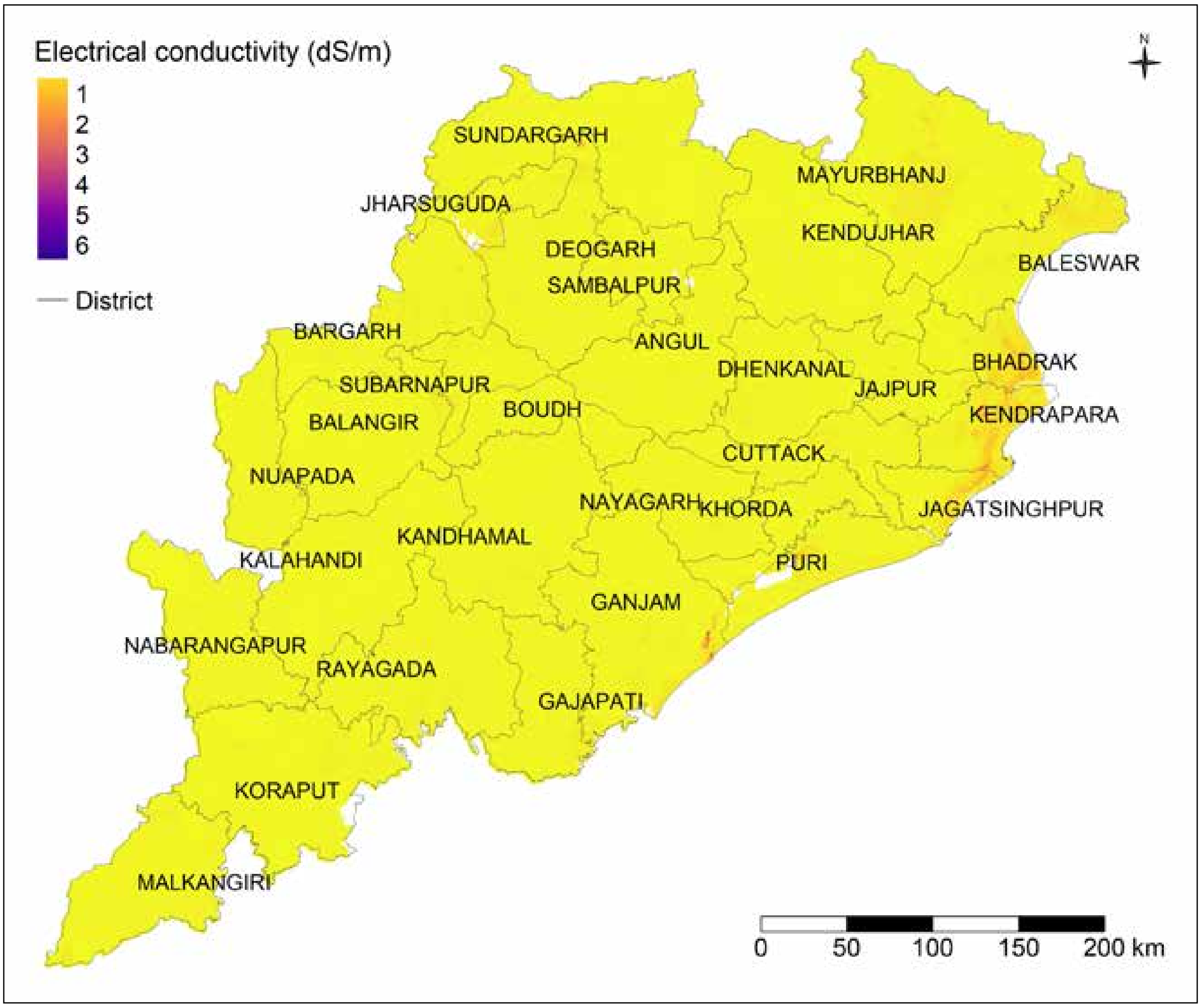


Figure 5.5. State level electrical conductivity (dS/m).

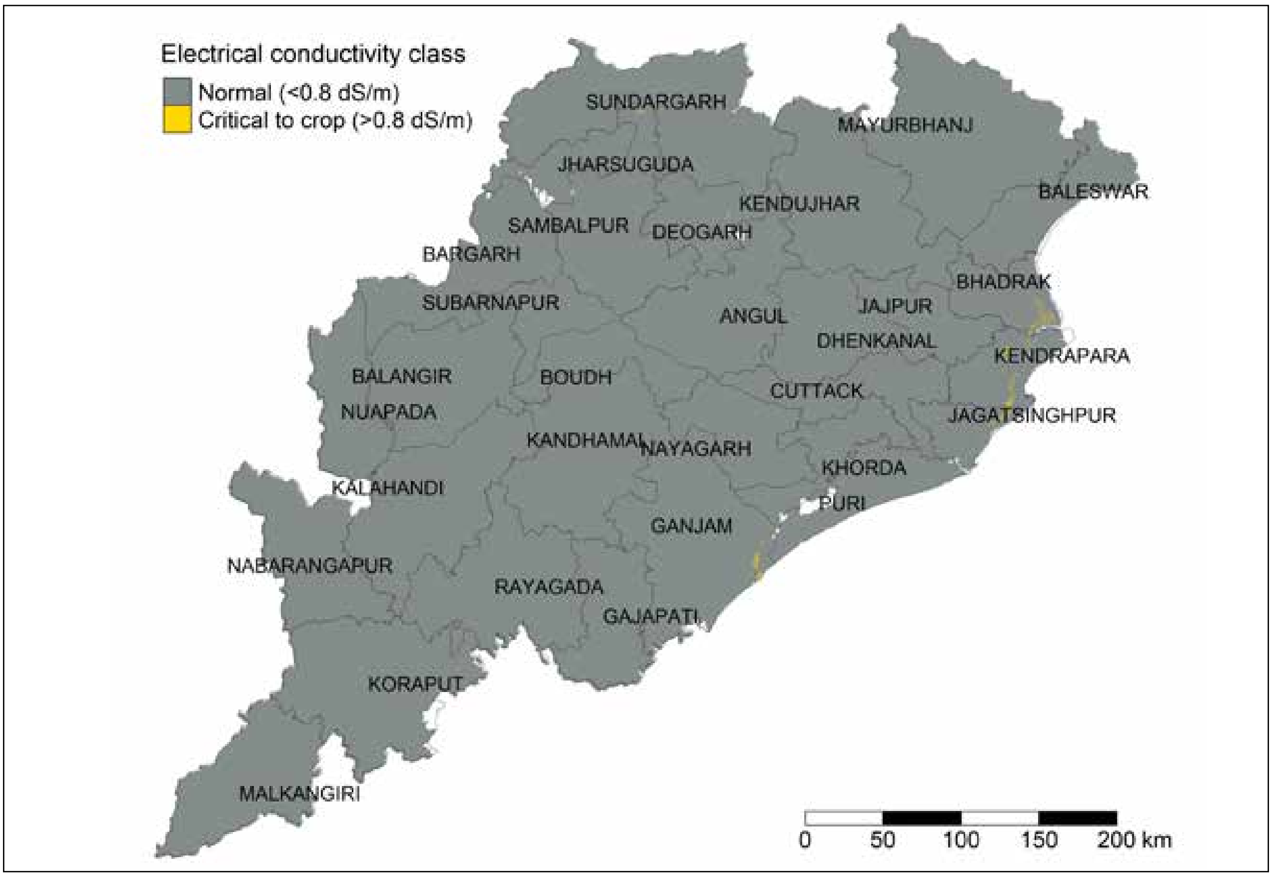


Figure 5.6. Classification of soils based on electrical conductivity.

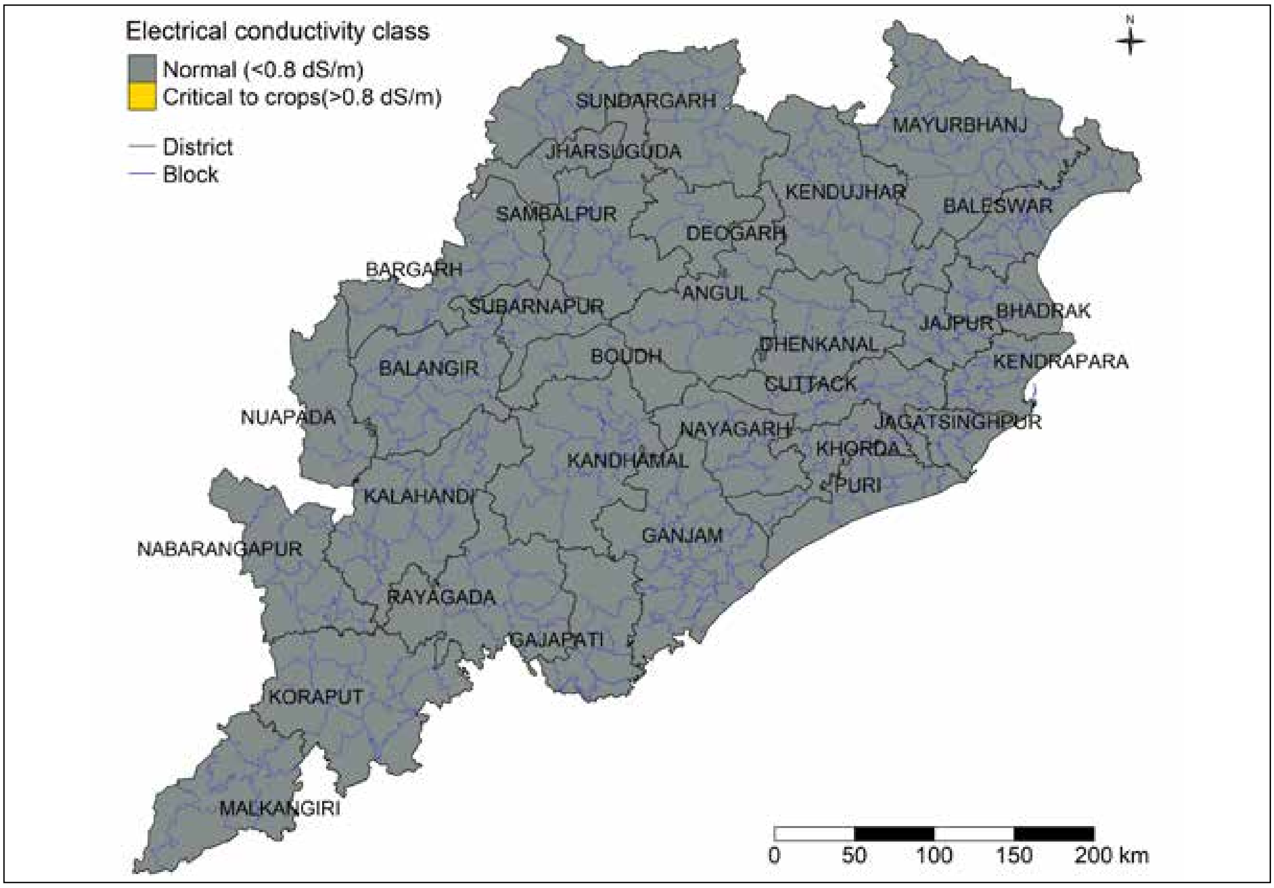


Figure 5.7. Block level soil classification of electrical conductivity.

Organic carbon (%)

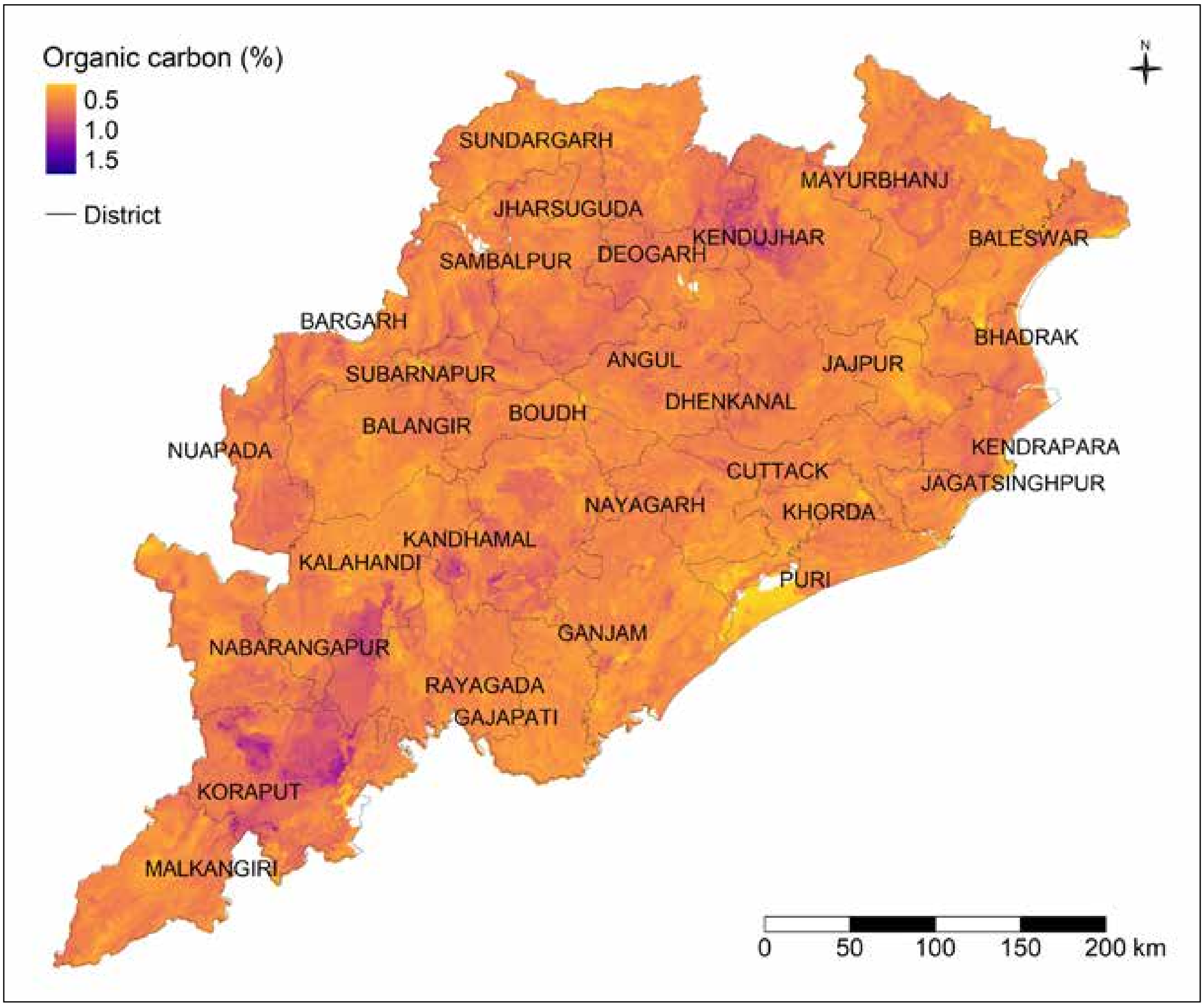


Figure 5.8. State level organic carbon (%).

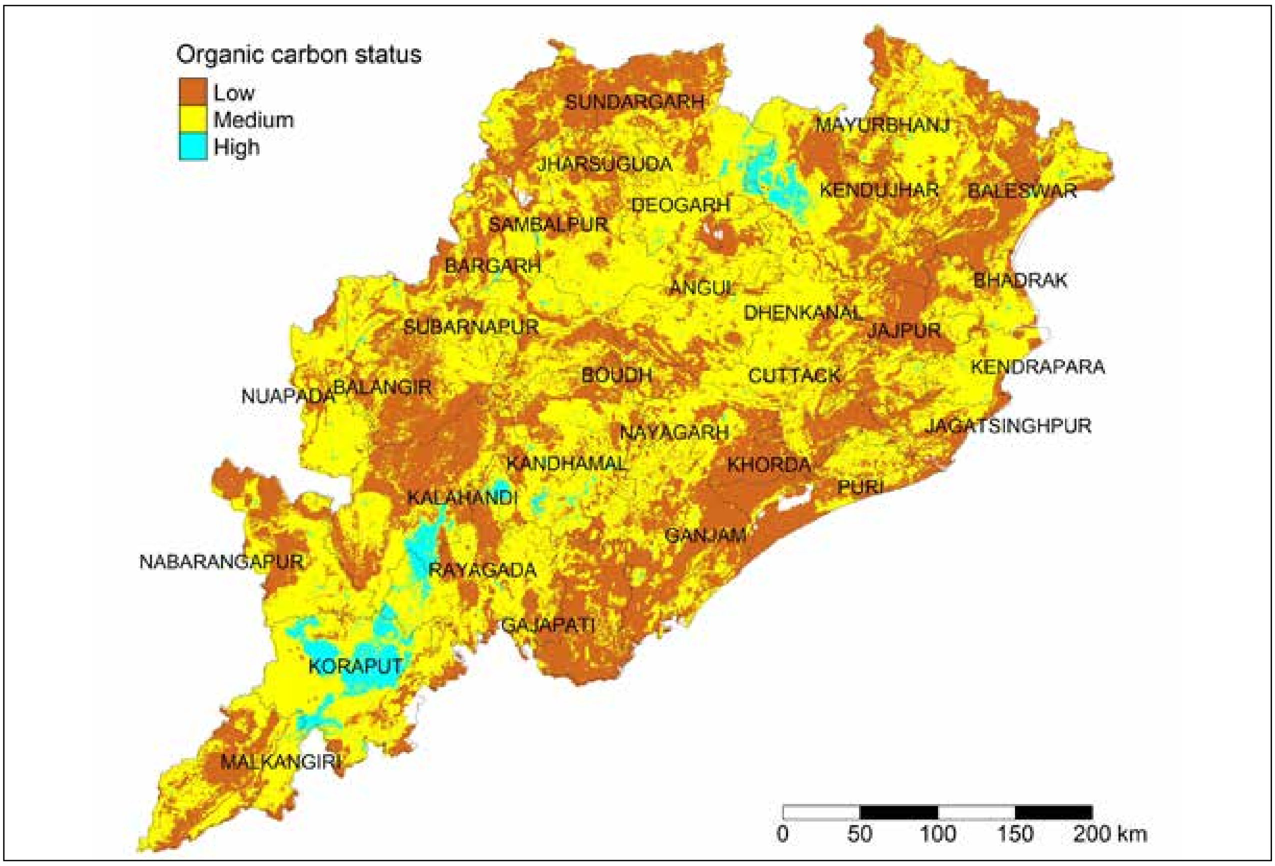


Figure 5.9. Soil organic carbon status.

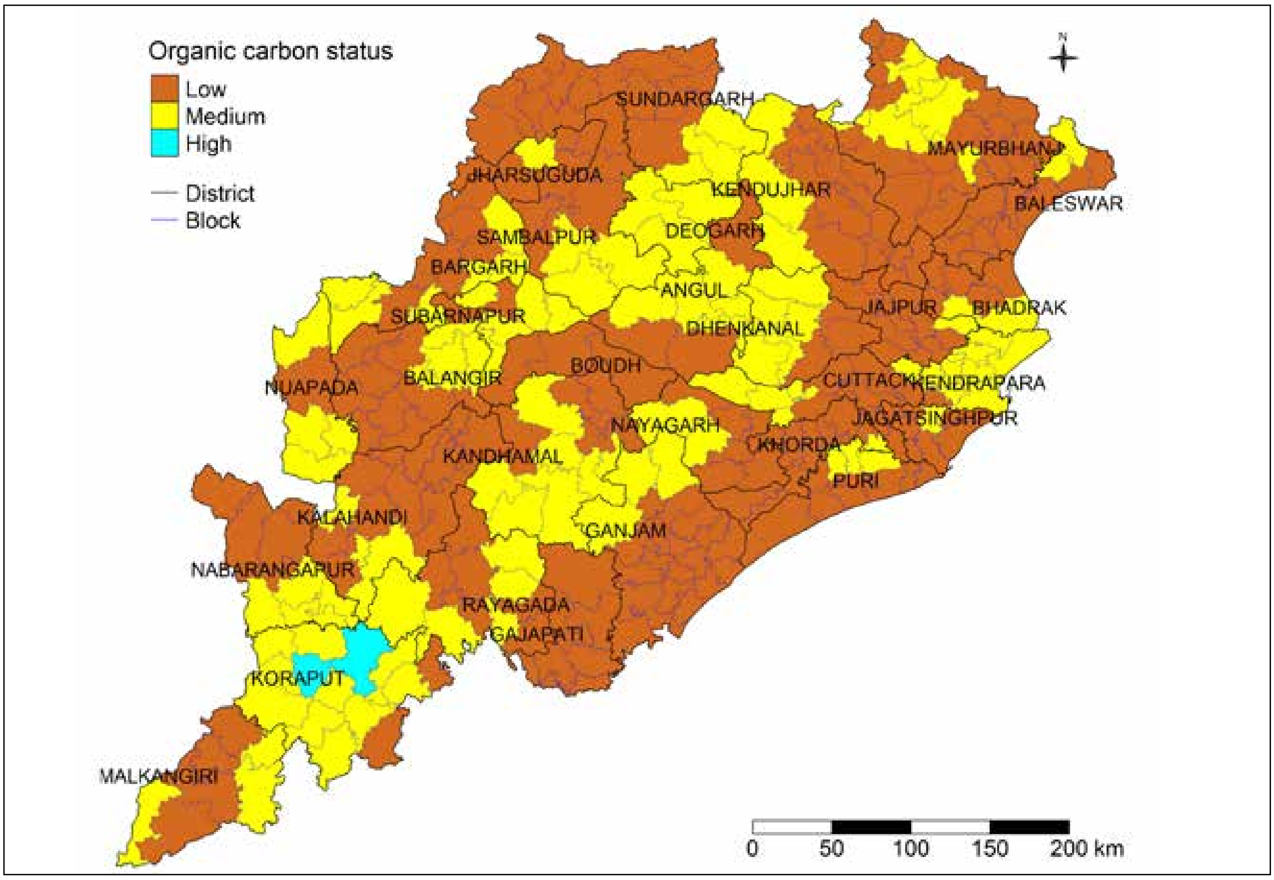


Figure 5.10. Status of soil organic carbon using values aggregated at block level.

Available phoshorous (mg/kg)

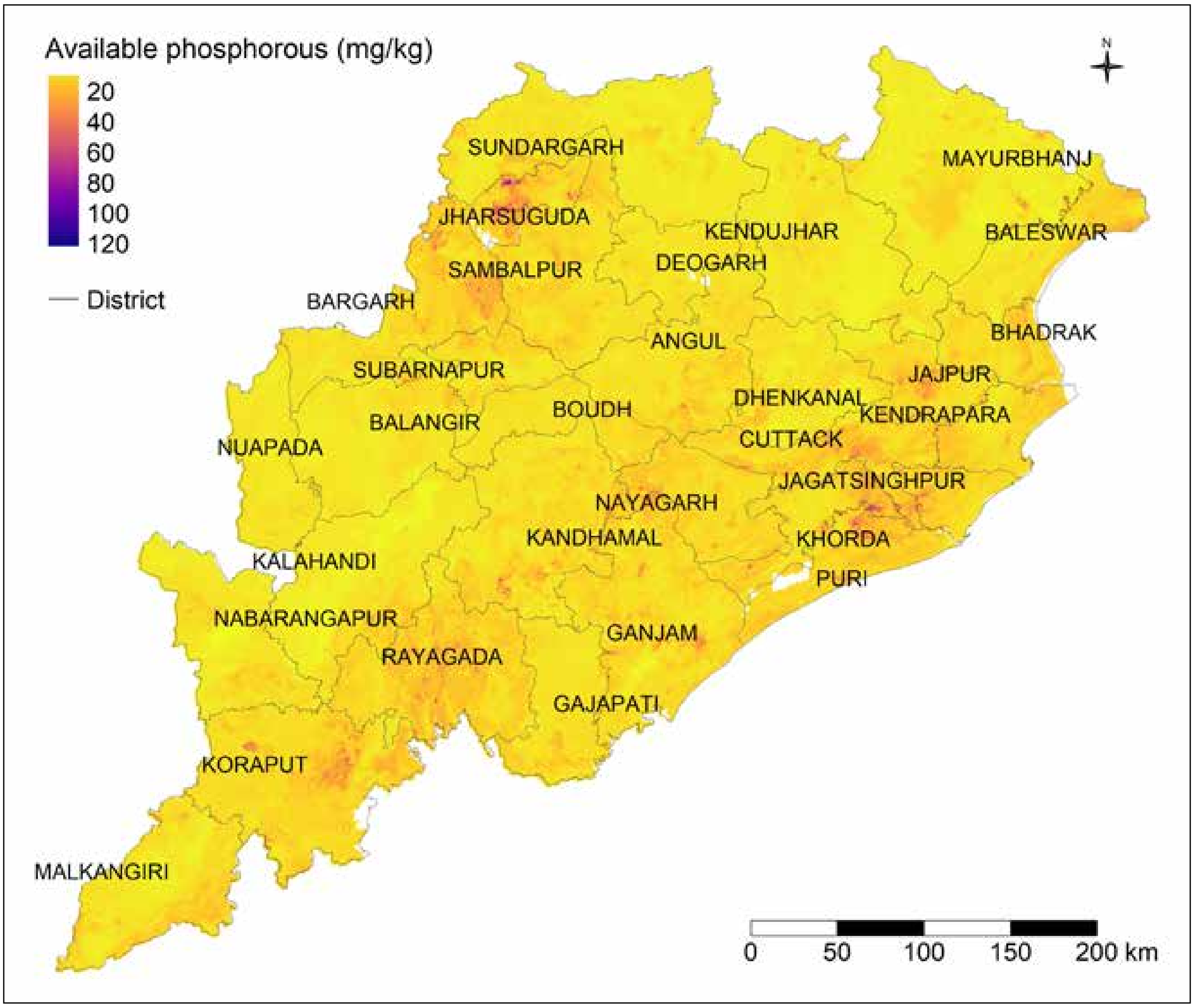


Figure 5.11. State level available phosphorous (mg/kg).

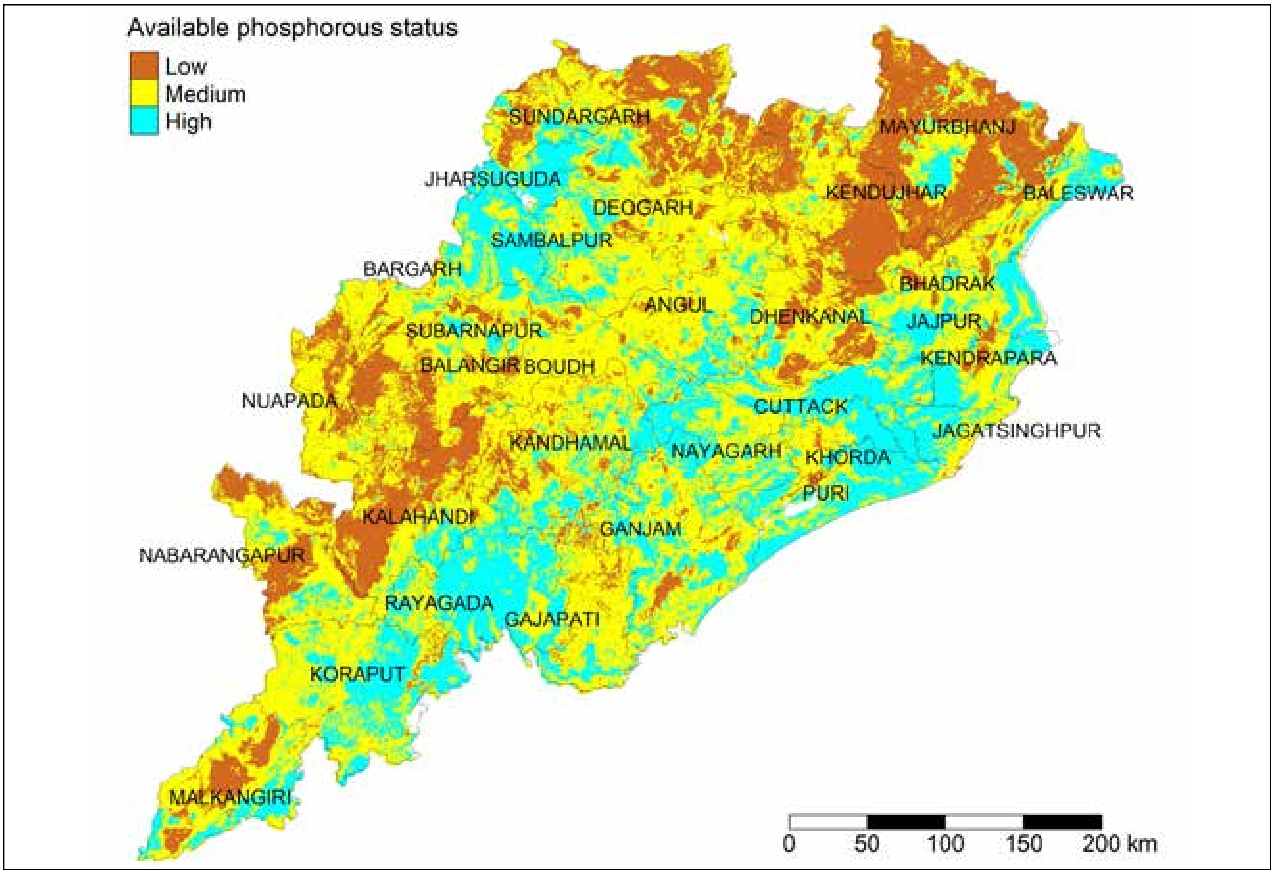


Figure 5.12. Available phosphorous status in the soils.

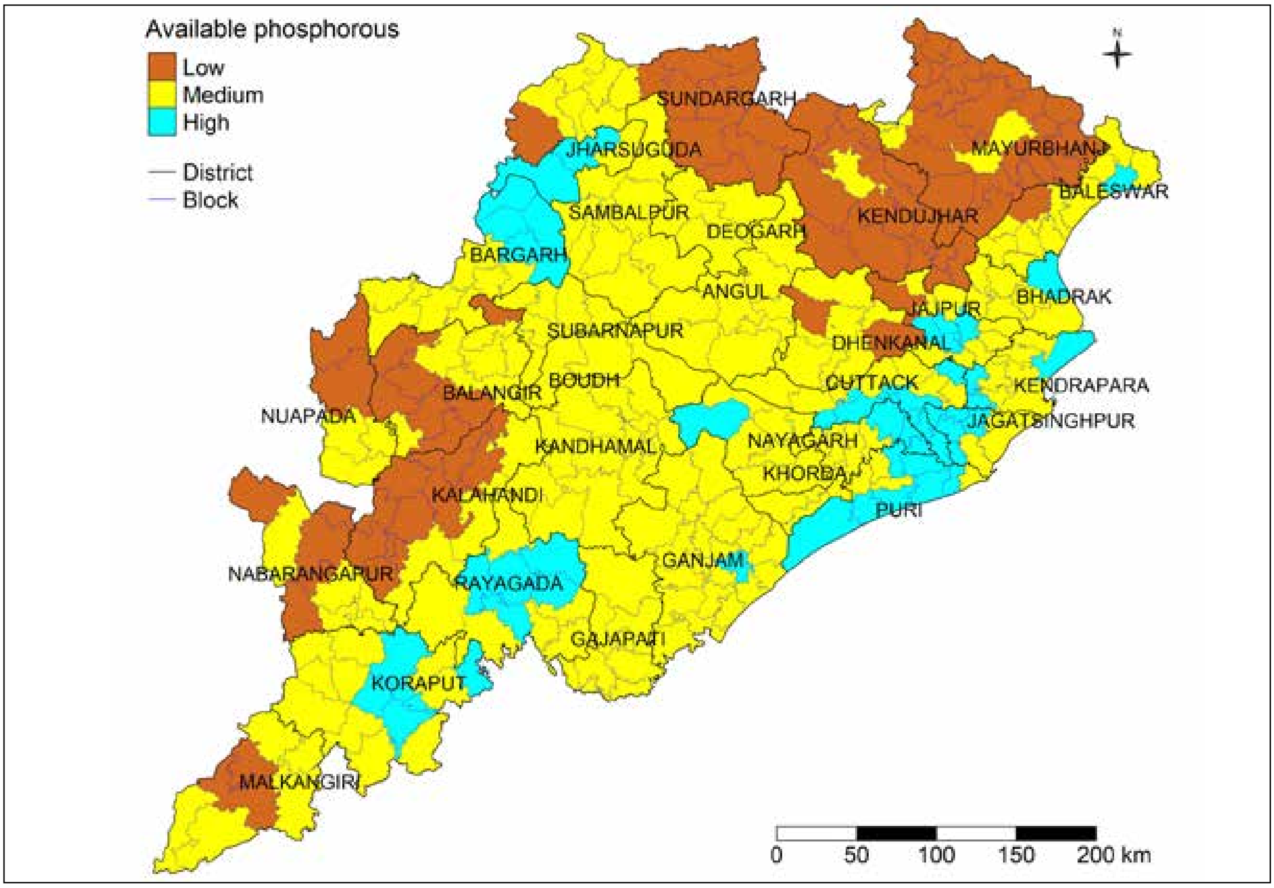


Figure 5.13. Available phosphorous using values aggregated at block level.

Exchangeable potassium (mg/kg)

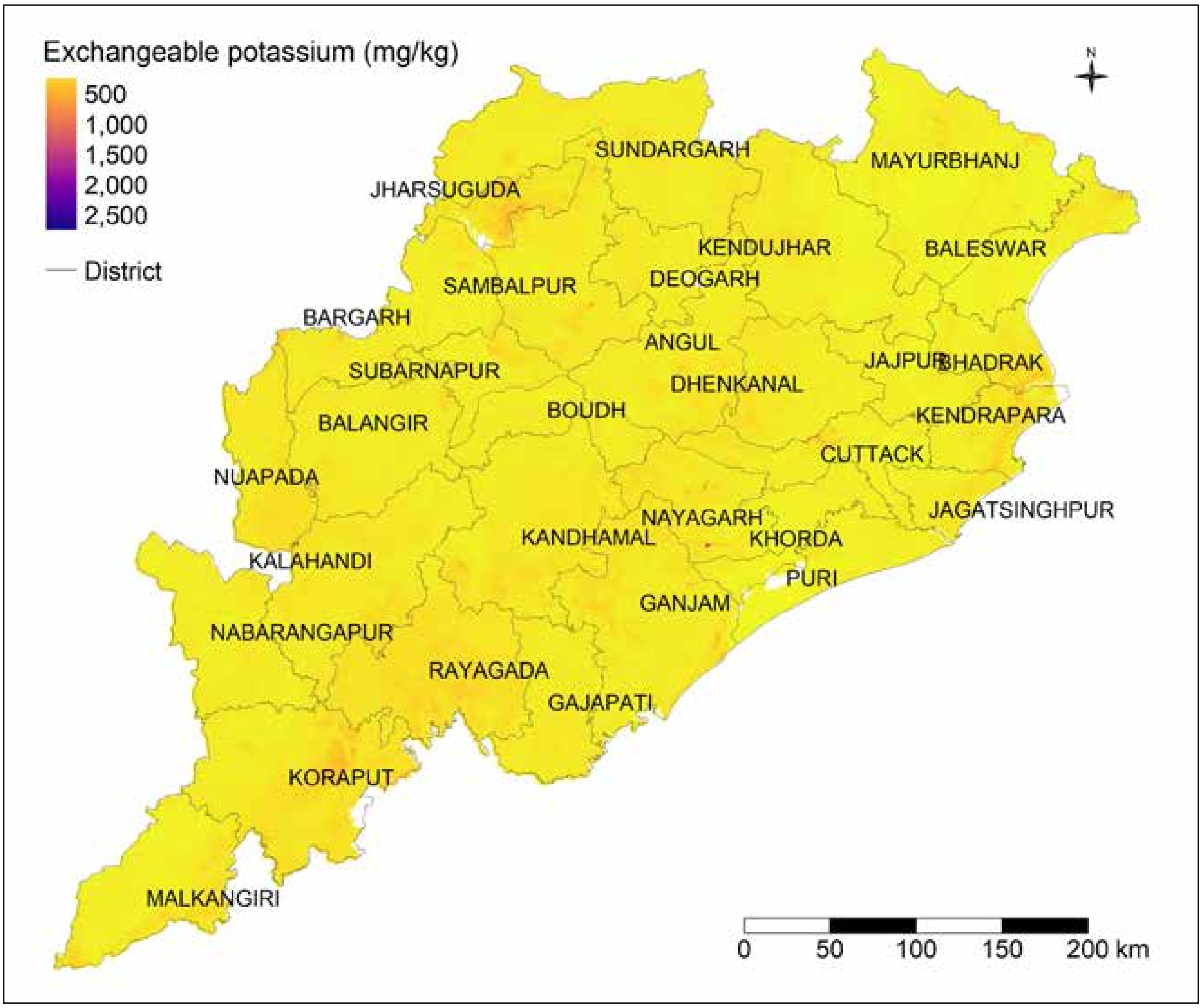


Figure 5.14. State level exchangeable potassium (mg/kg).

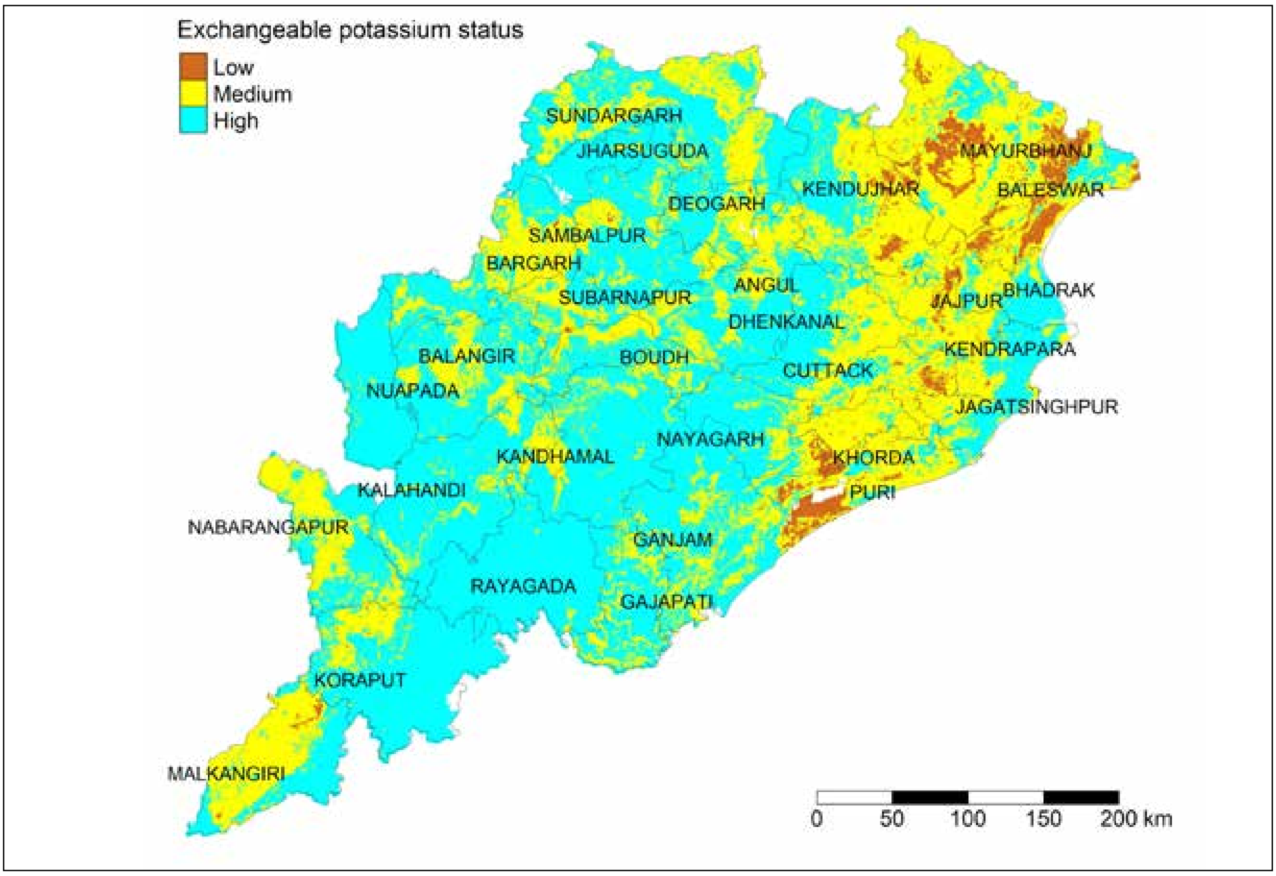


Figure 5.15. Exchangeable potassium status in the soils.

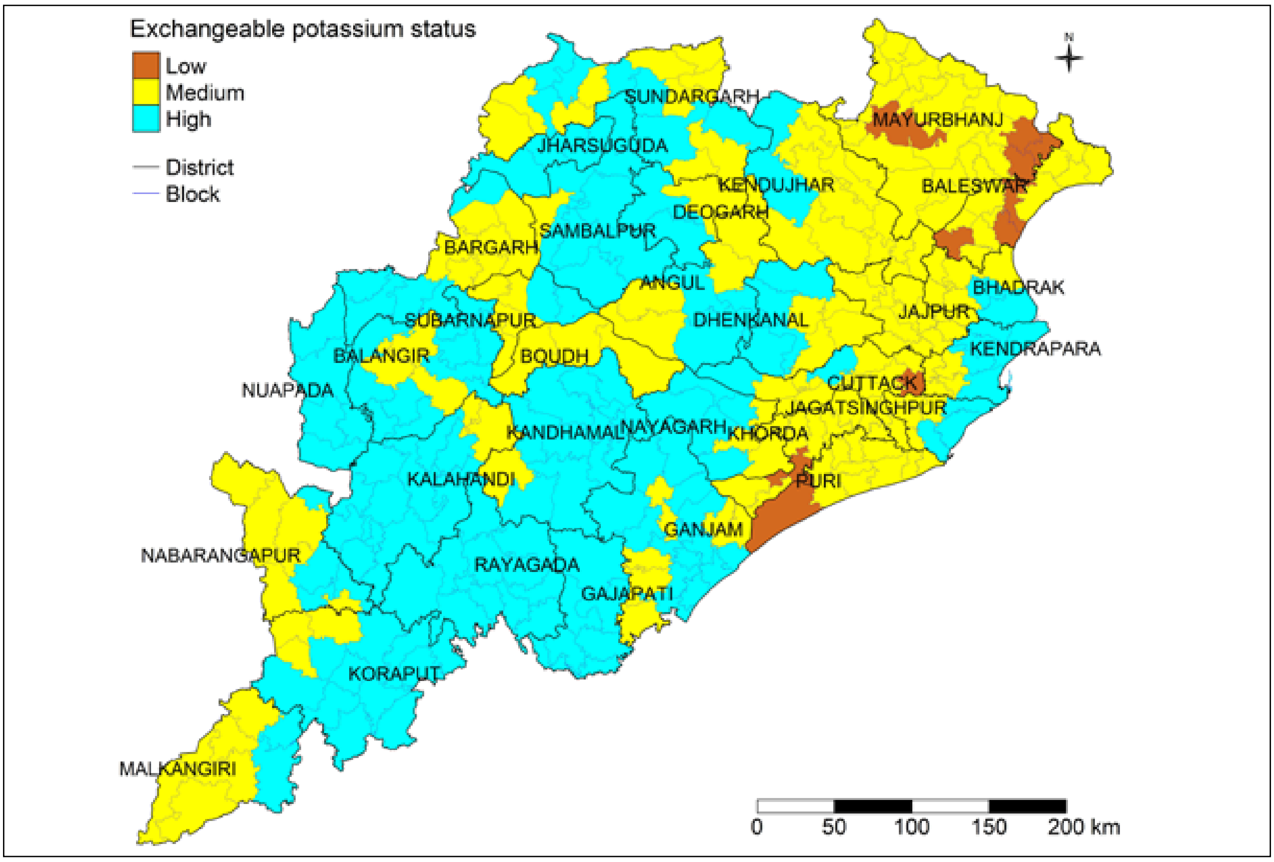


Figure 5.16. Exchangeable potassium using values aggregated at block level.

Available Sulfur (mg/kg)

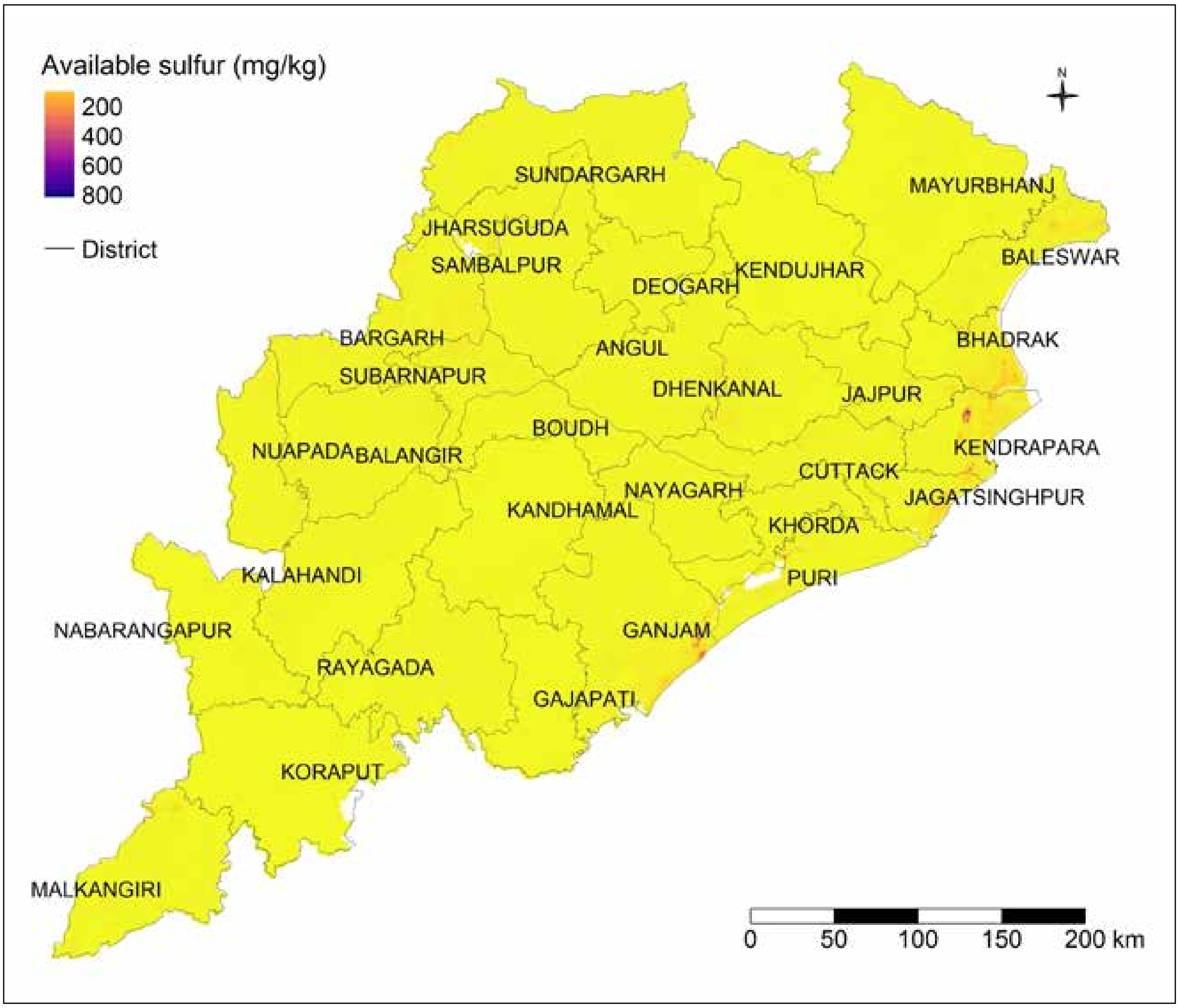


Figure 5.17. State level available sulfur (mg/kg).

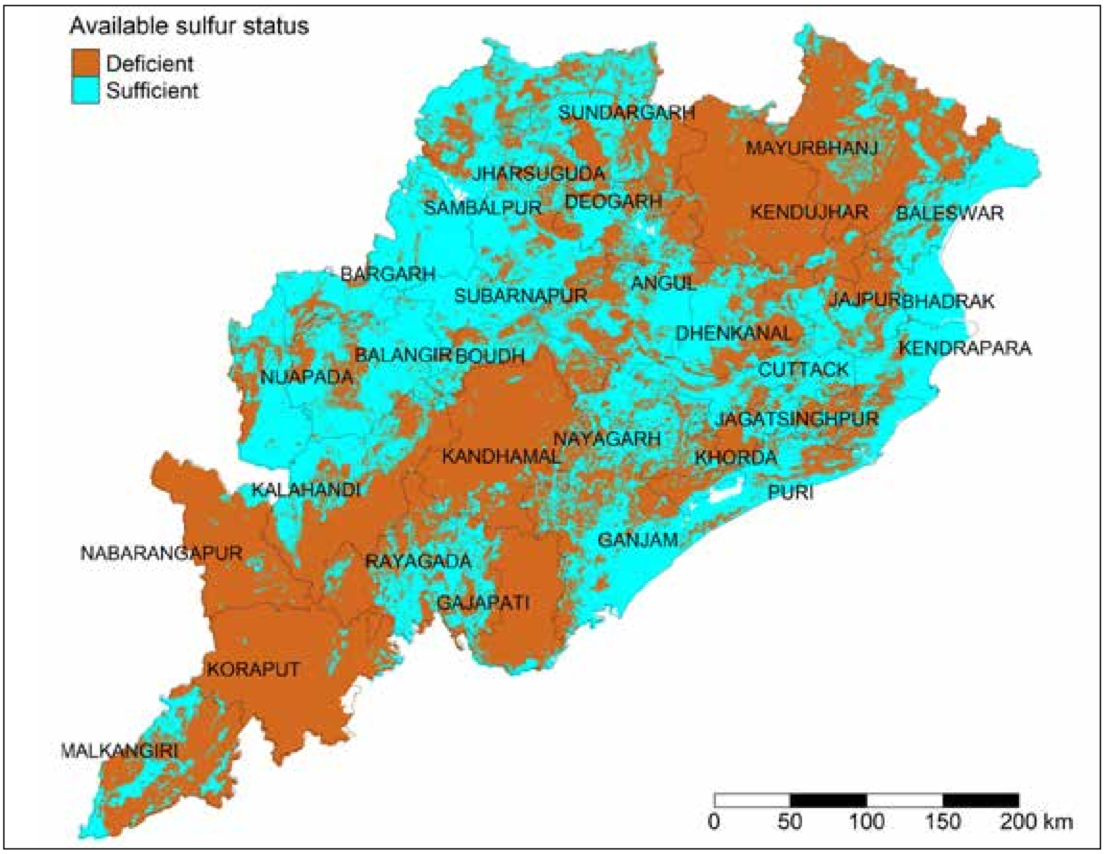


Figure 5.18. Available sulfur status in soils.

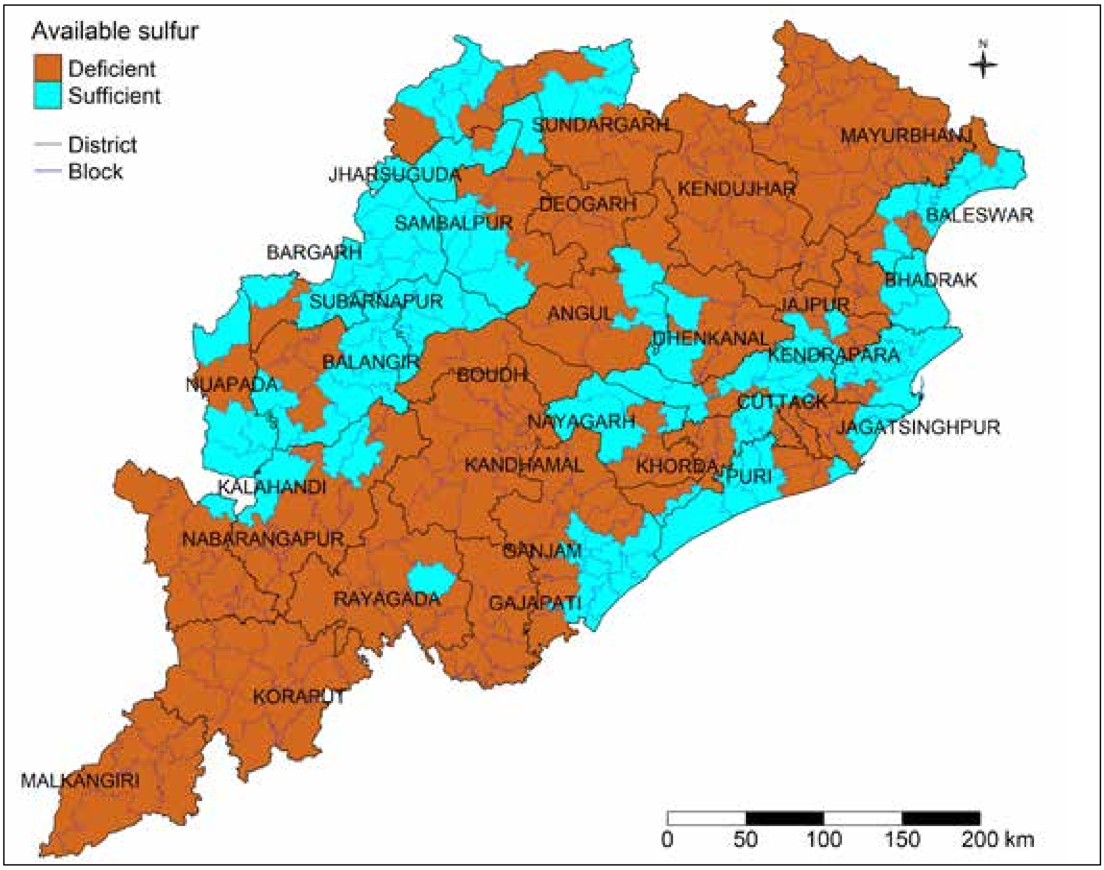


Figure 5.19. Available sulfur using aggregated values at block level.

Available Boron (mg/kg)

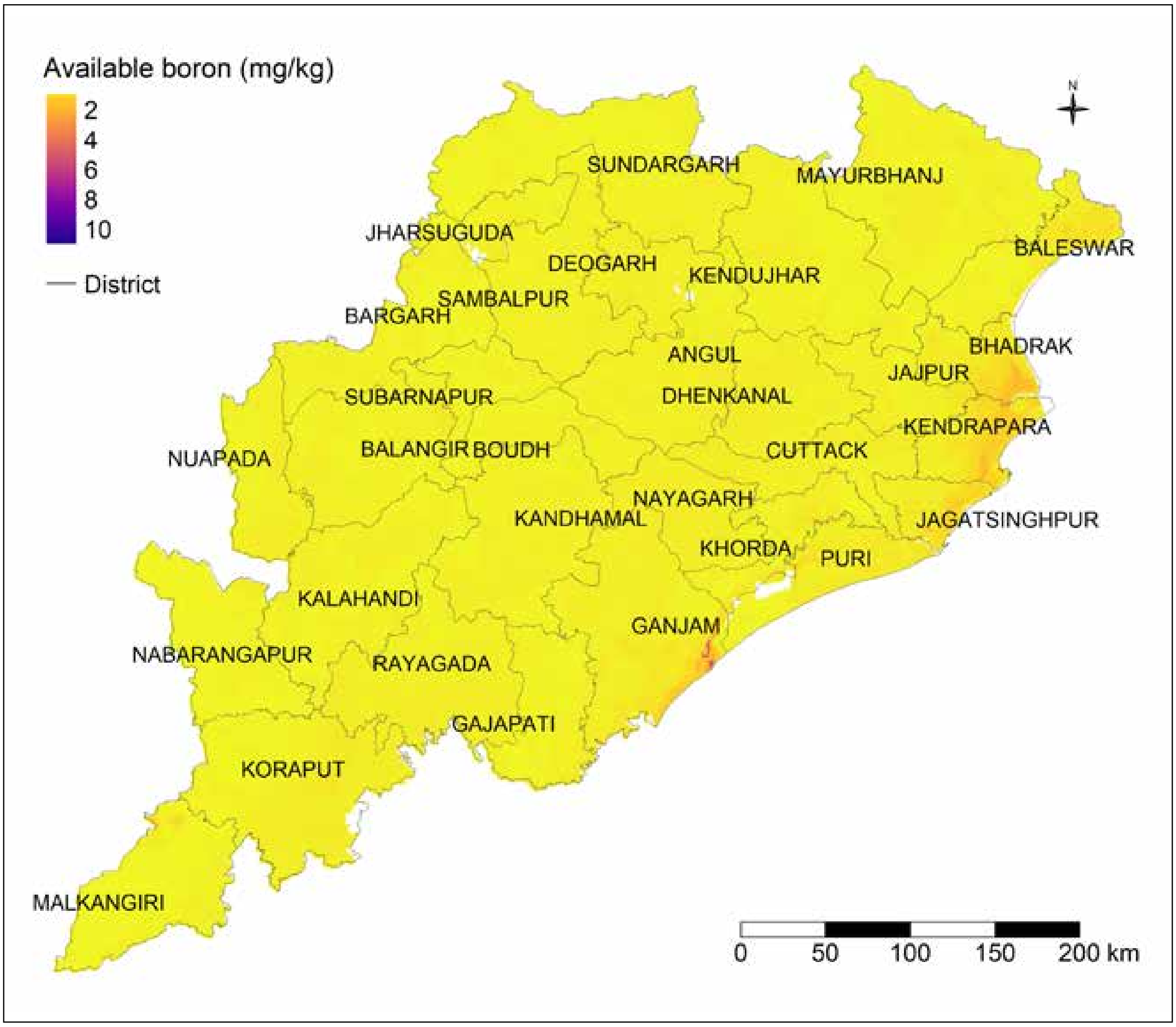


Figure 5.20. State level available boron (mg/kg).

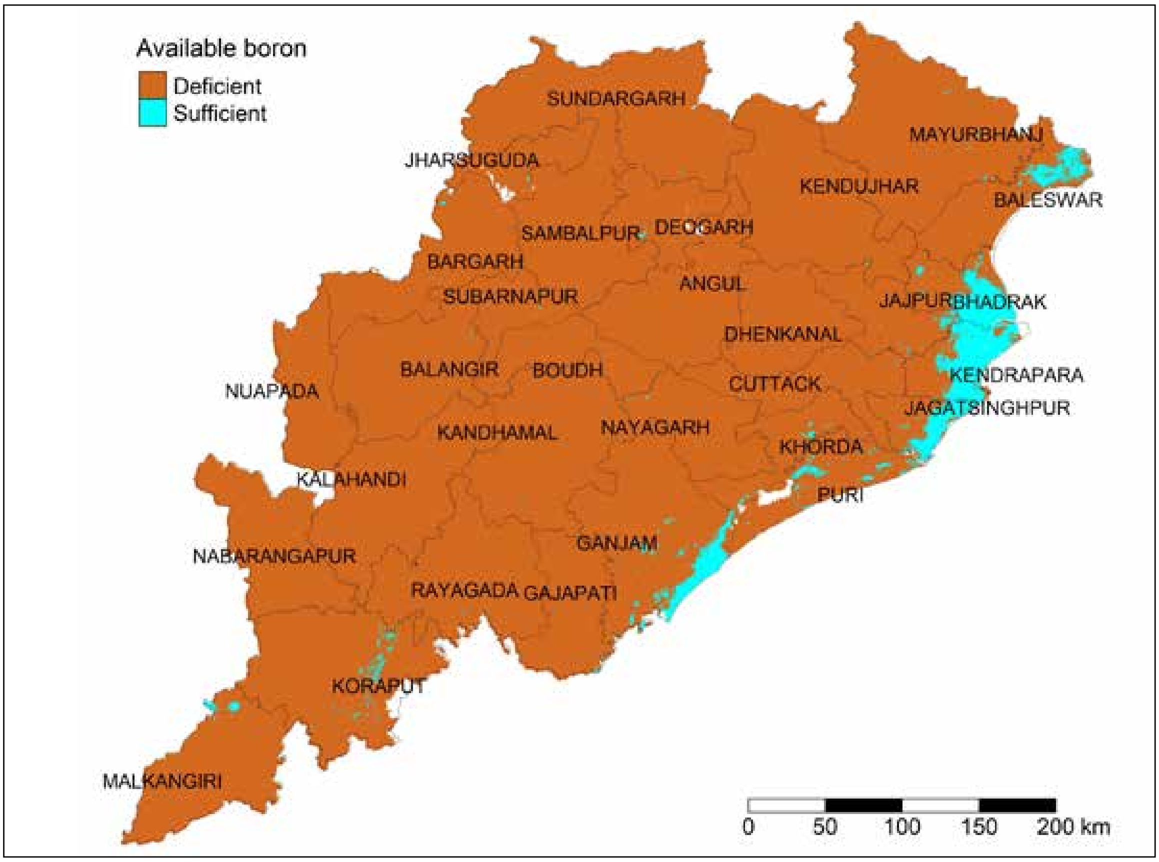


Figure 5.21. Available boron status in soils.

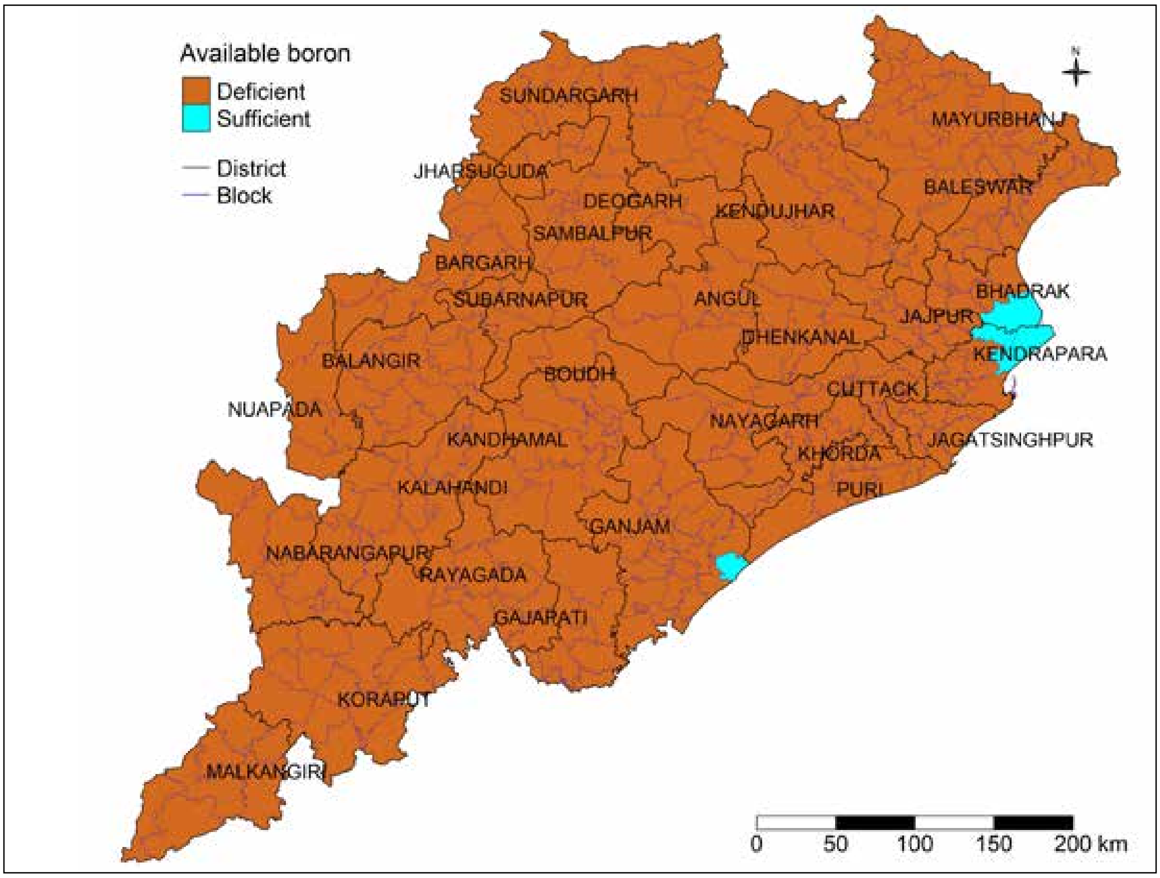


Figure 5.22. Available boron status using values aggregated at block level.

Available Zinc (mg/kg)

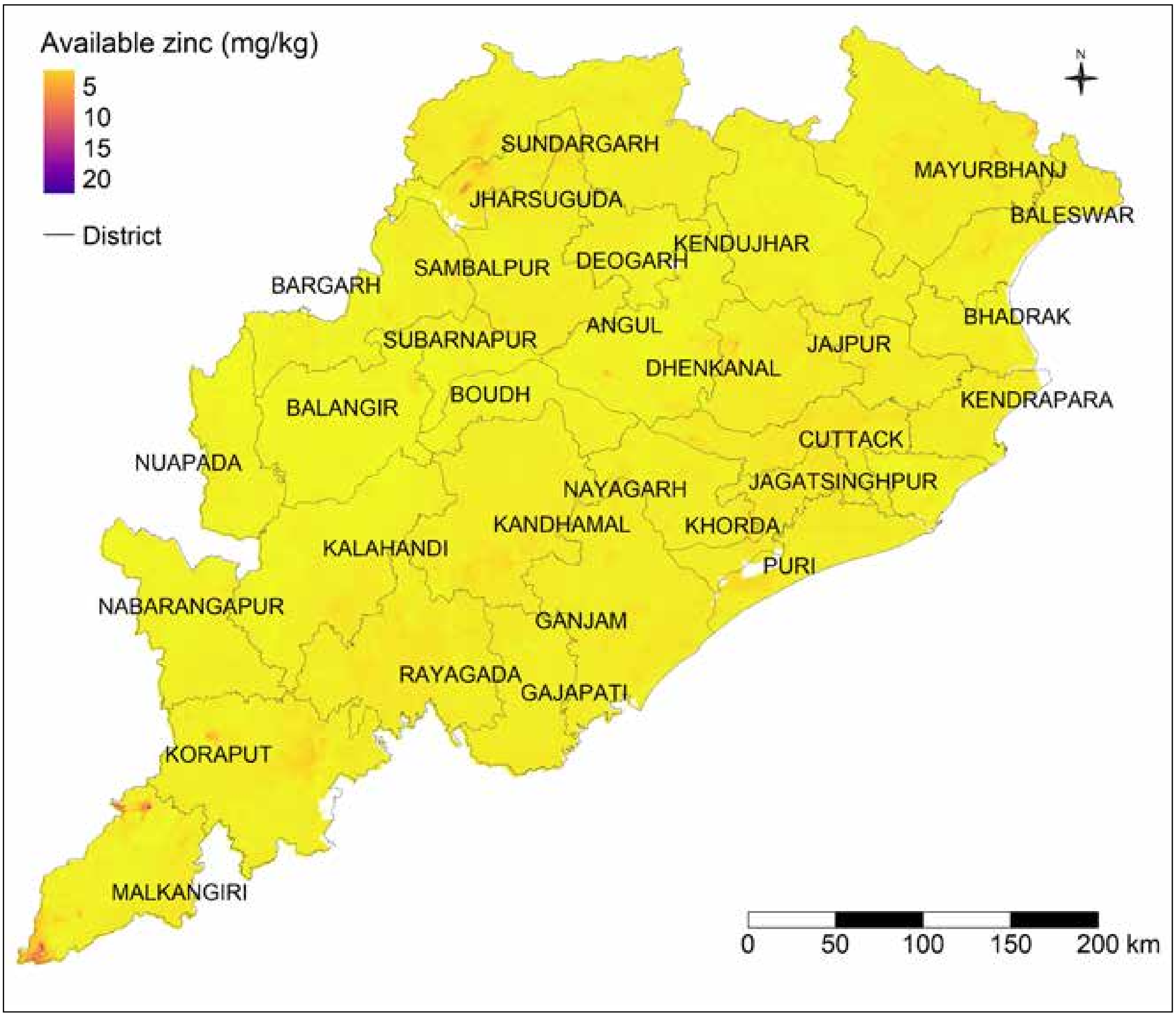


Figure 5.23. State level available zinc (mg/kg).

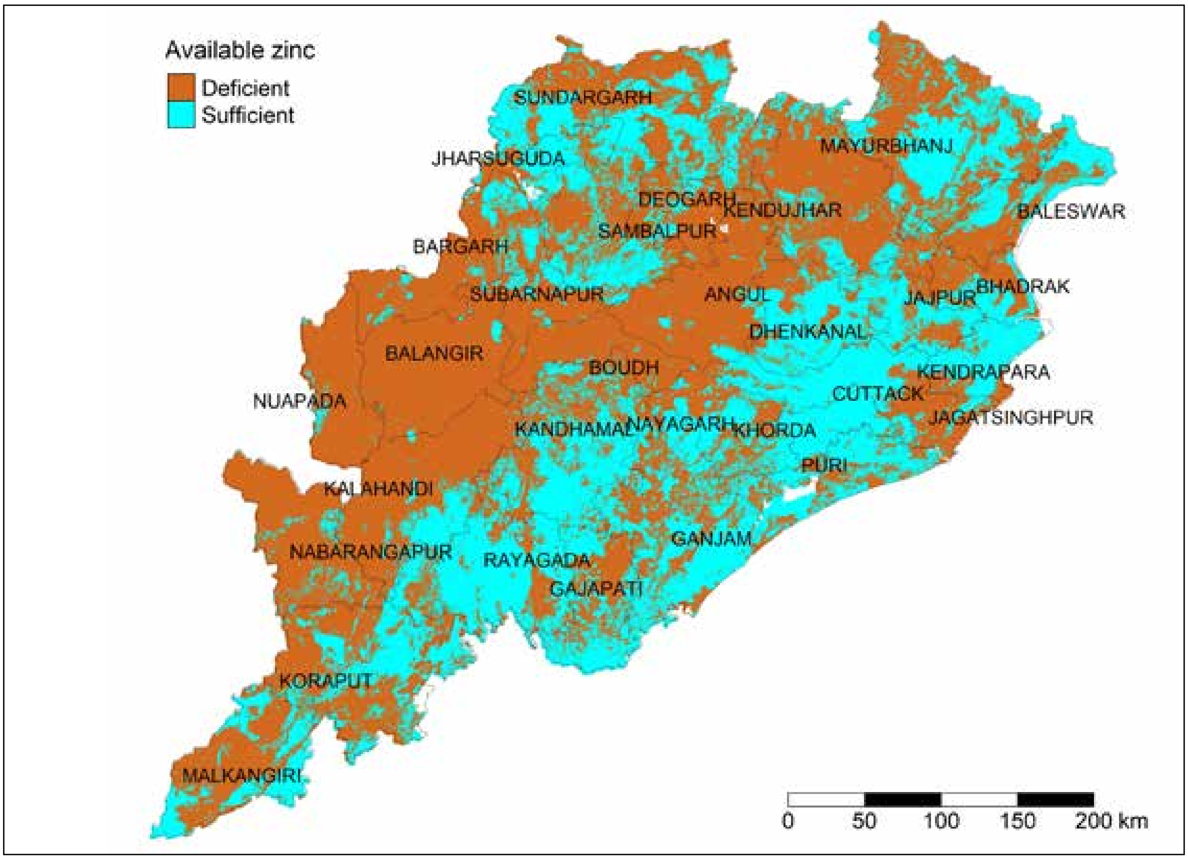


Figure 5.24. Available zinc status in soils.

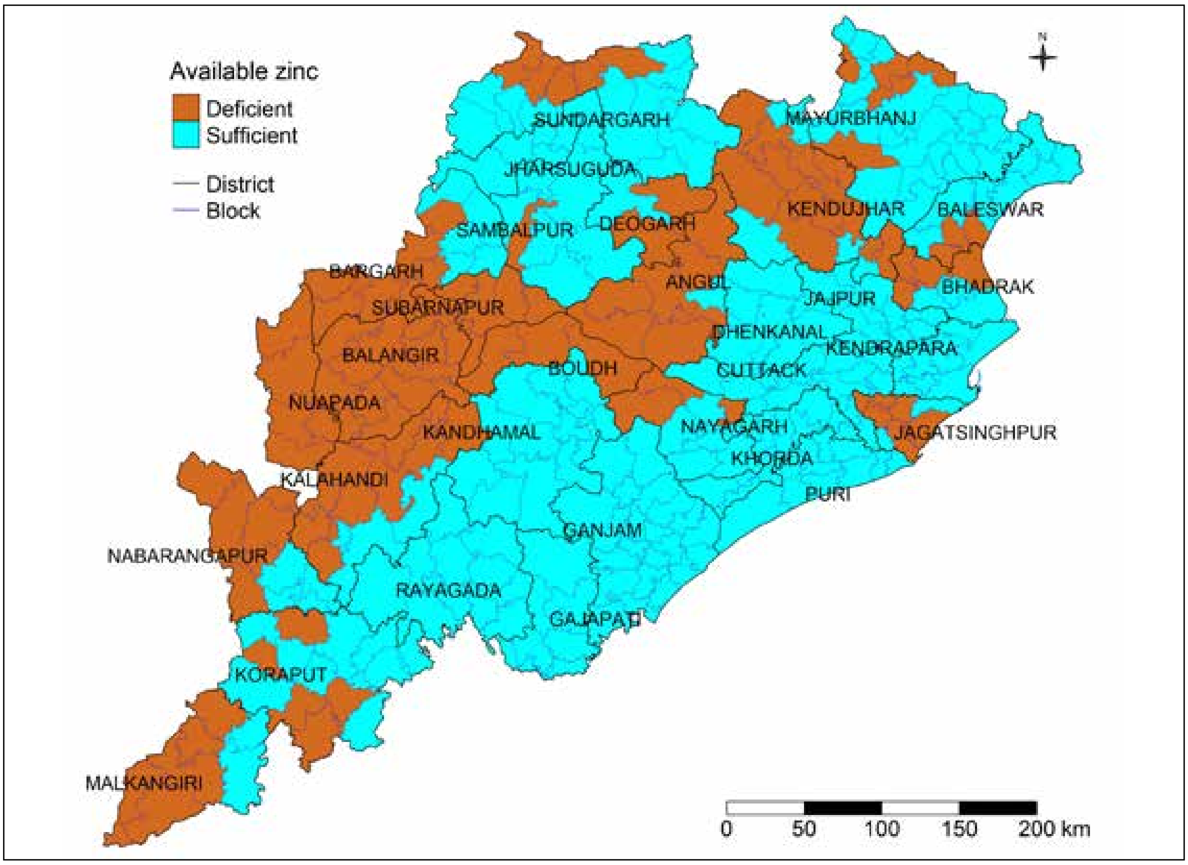


Figure 5.25. Available zinc status using aggregated values at block level.

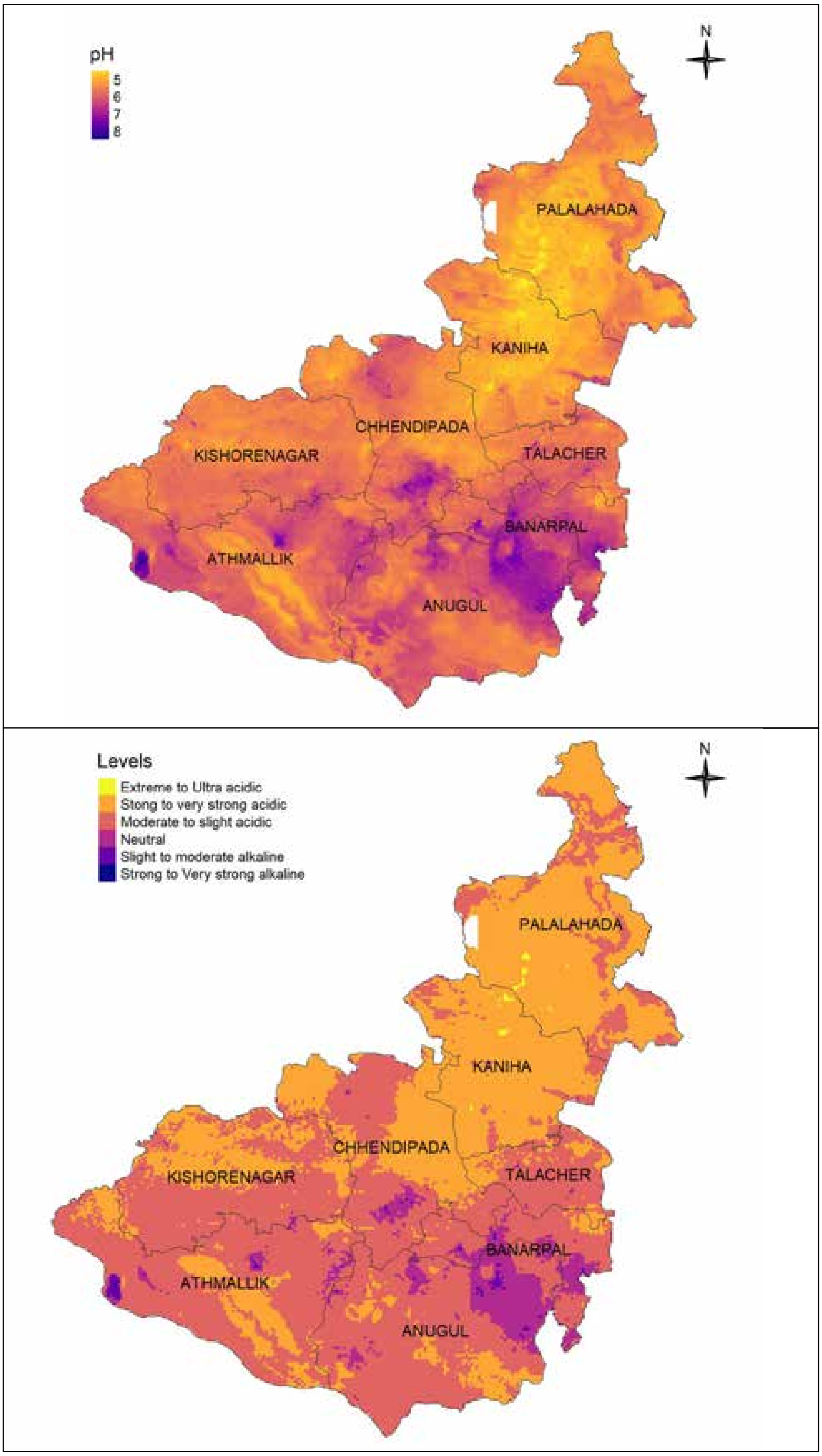


Figure 5.26. pH status in soils of Angul district.

Electrical conductivity

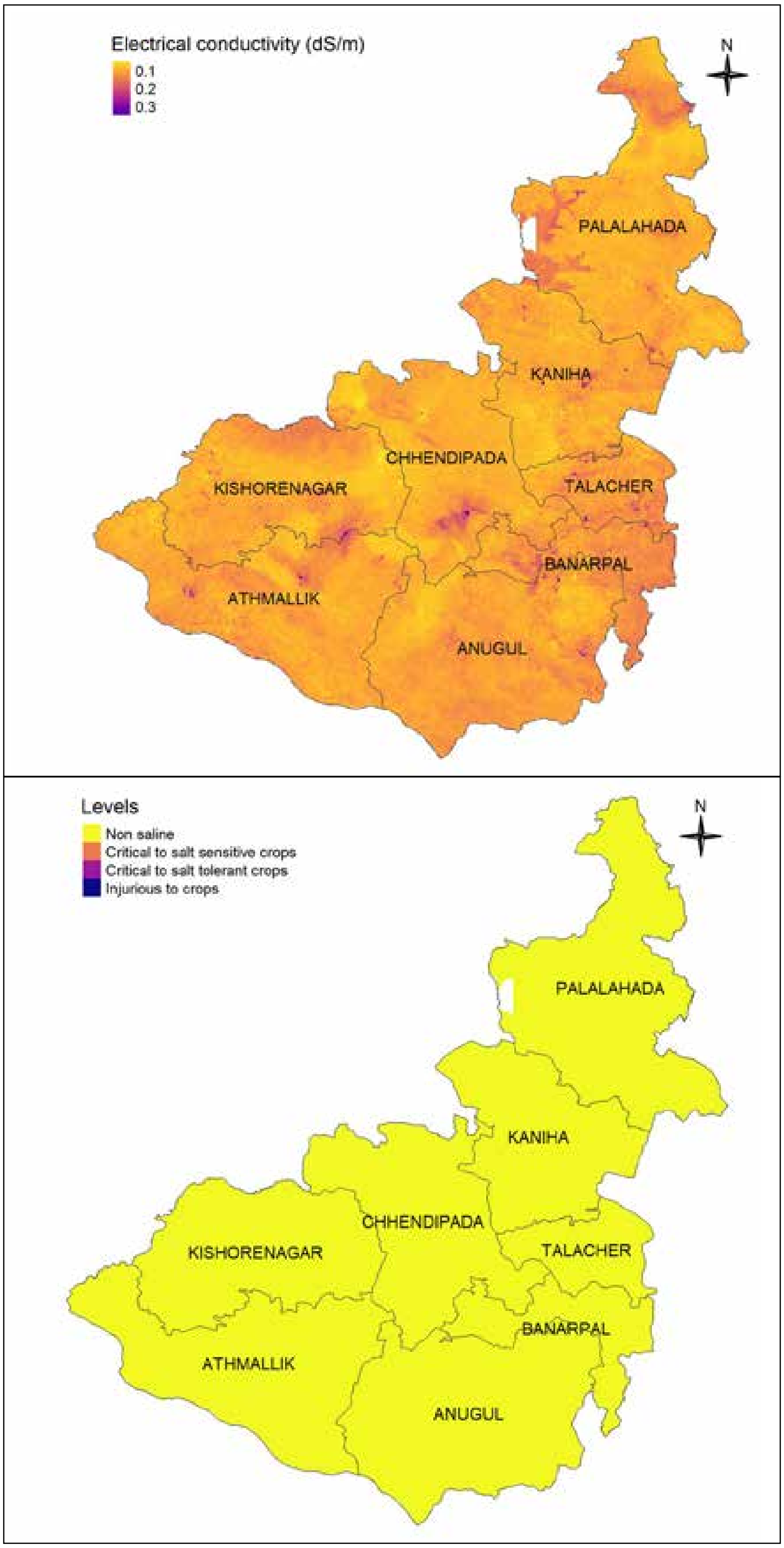


Figure 5.27. Status of electrical conductivity in soils of Angul district.

Organic carbon

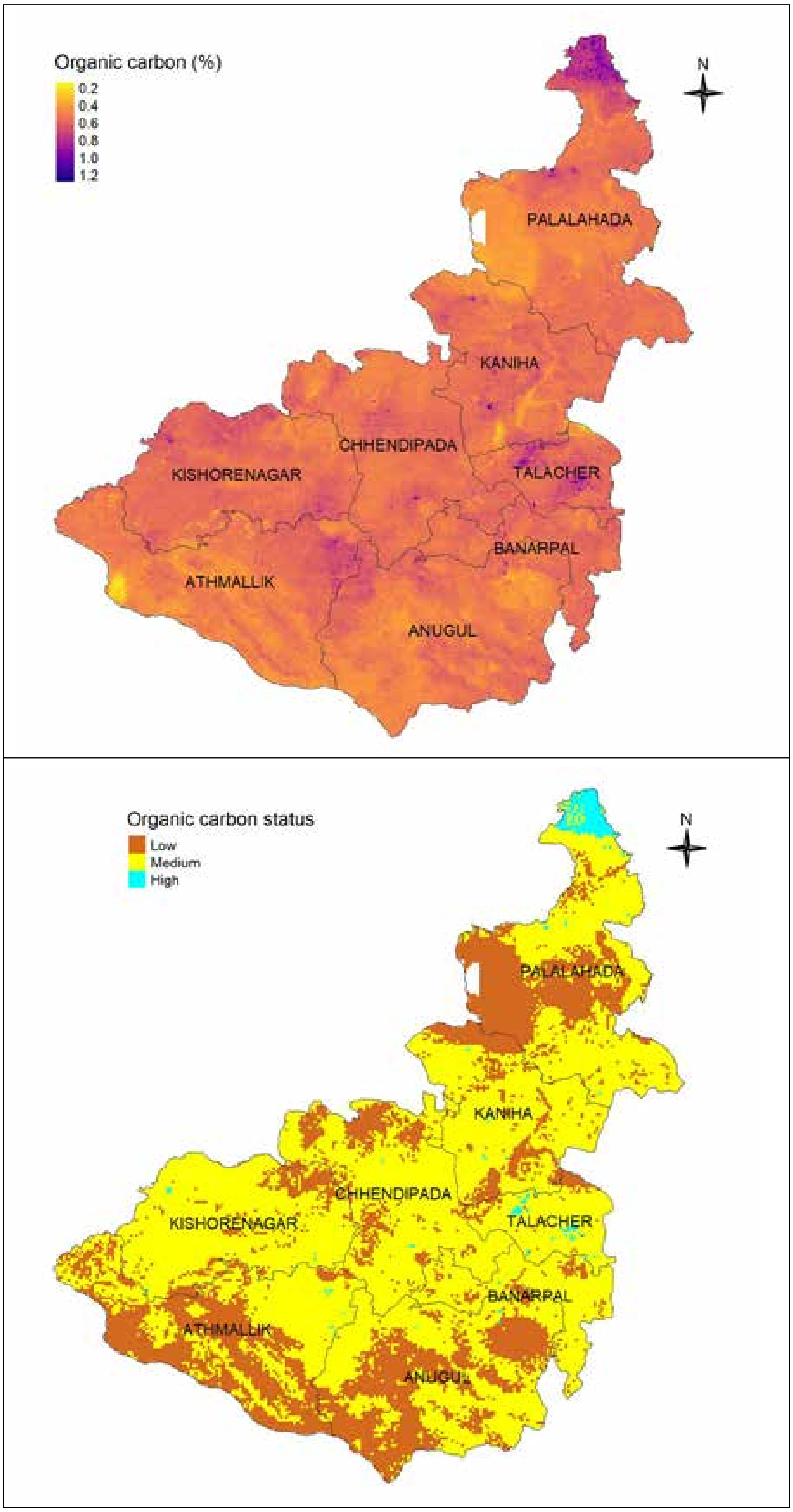


Figure 5.28. Organic carbon status in soils of Angul district.

Available Phosphorous

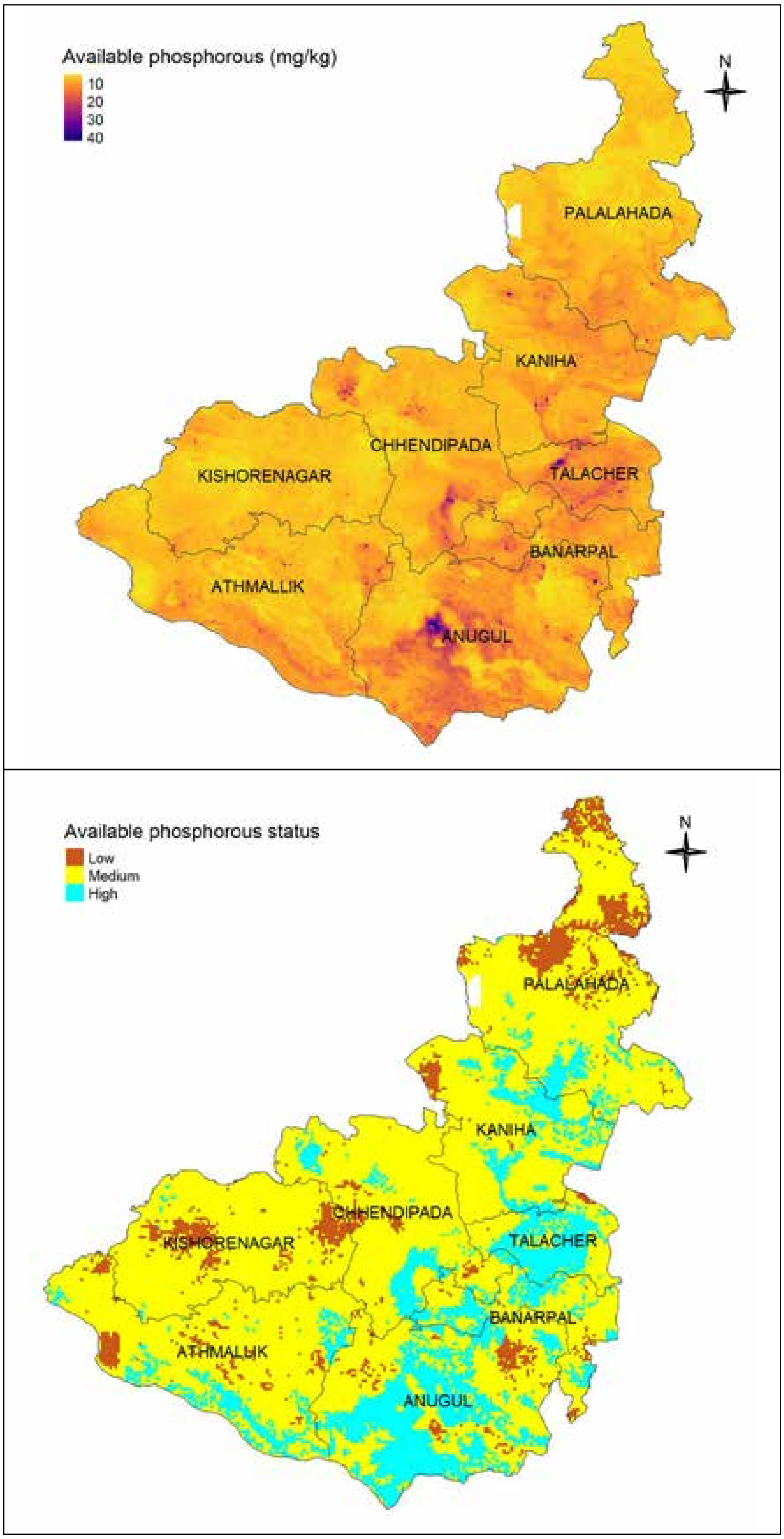


Figure 5.29. Status of available phosphorous in soils of Angul district.

Exchangeable Potassium

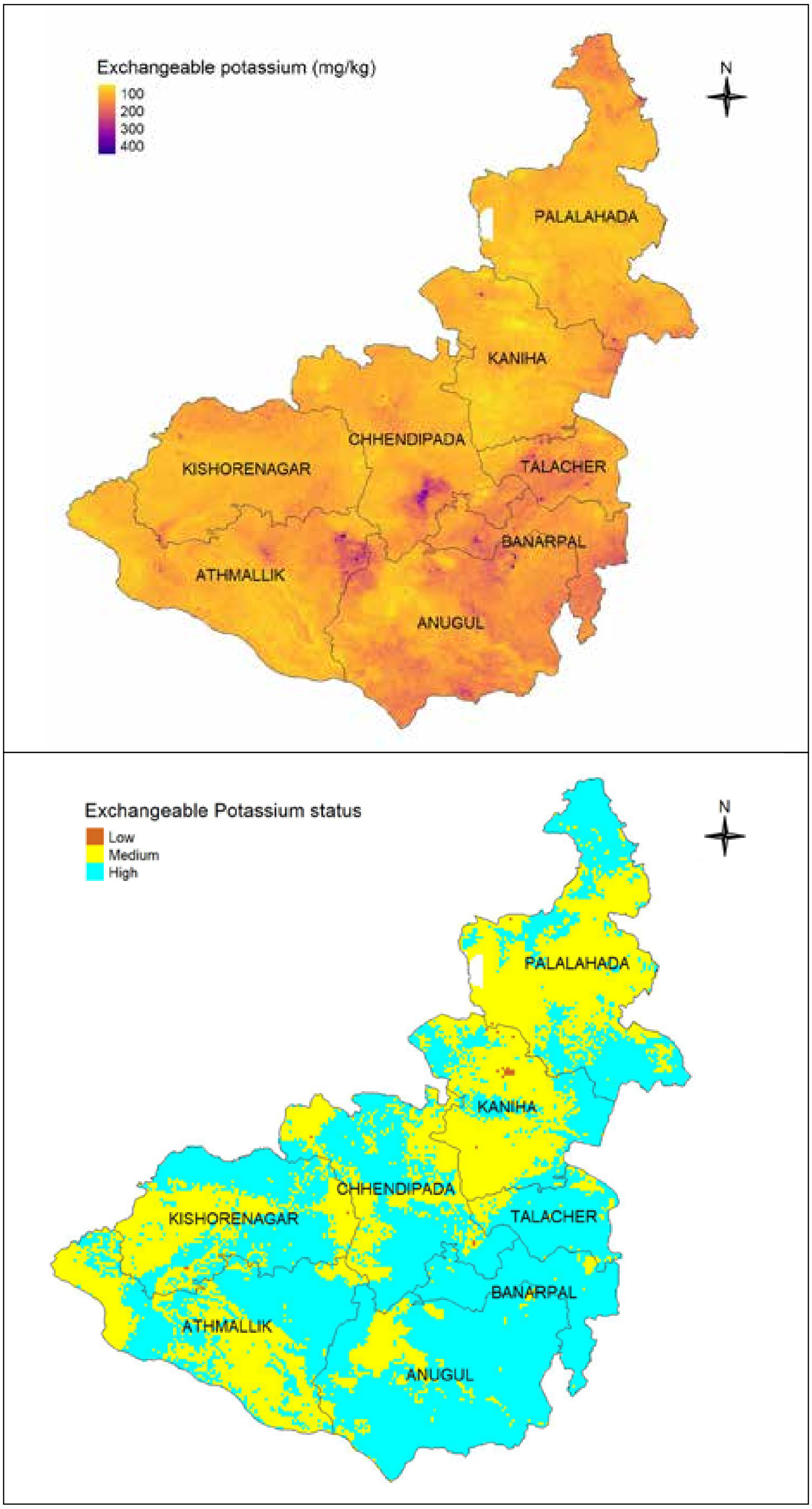


Figure 5.30. Status of exchangeable potassium in soils of Angul district.

Available Sulfur

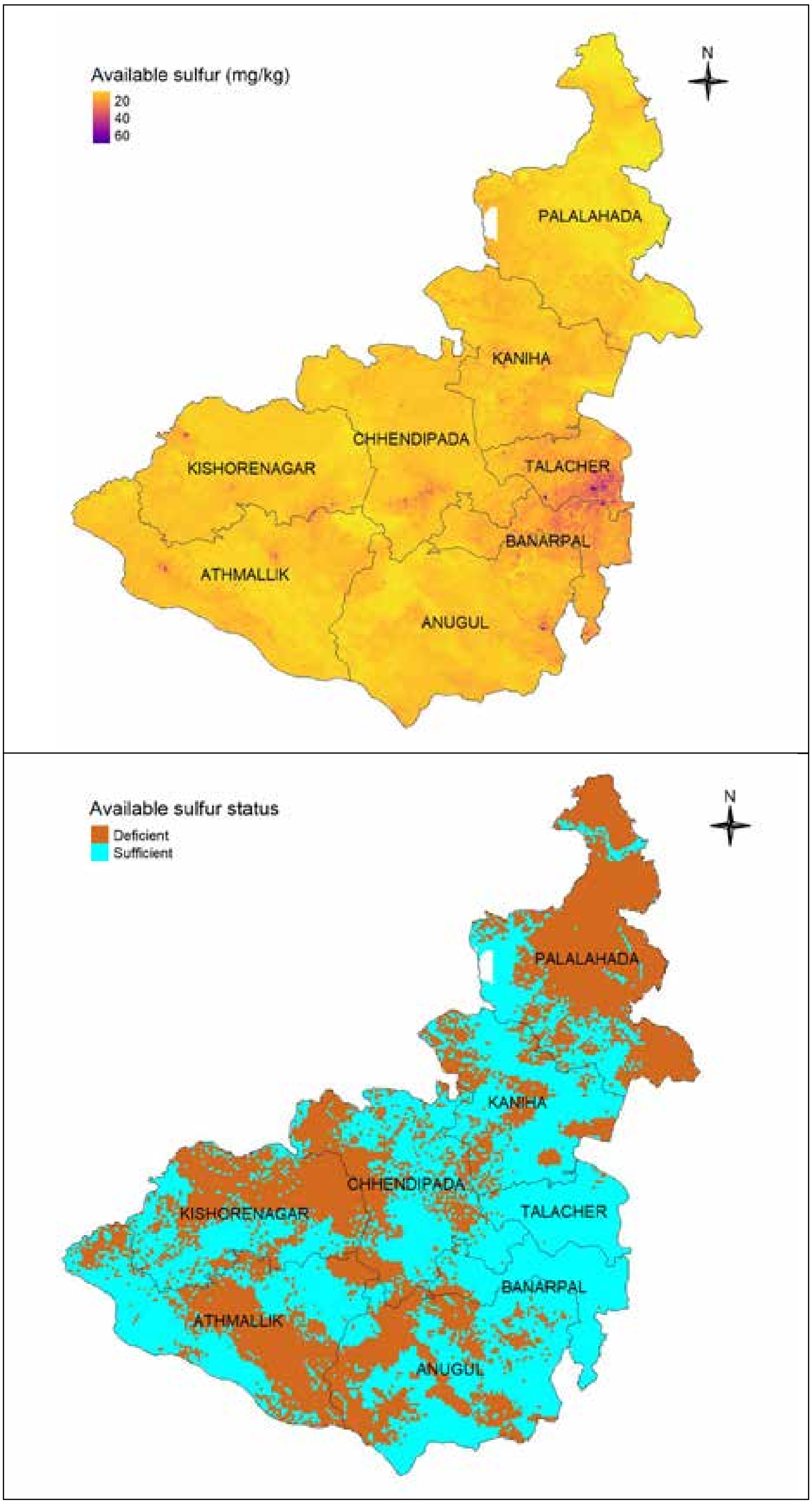


Figure 5.31. Status of available sulfur in soils of Angul district.

Available Boron

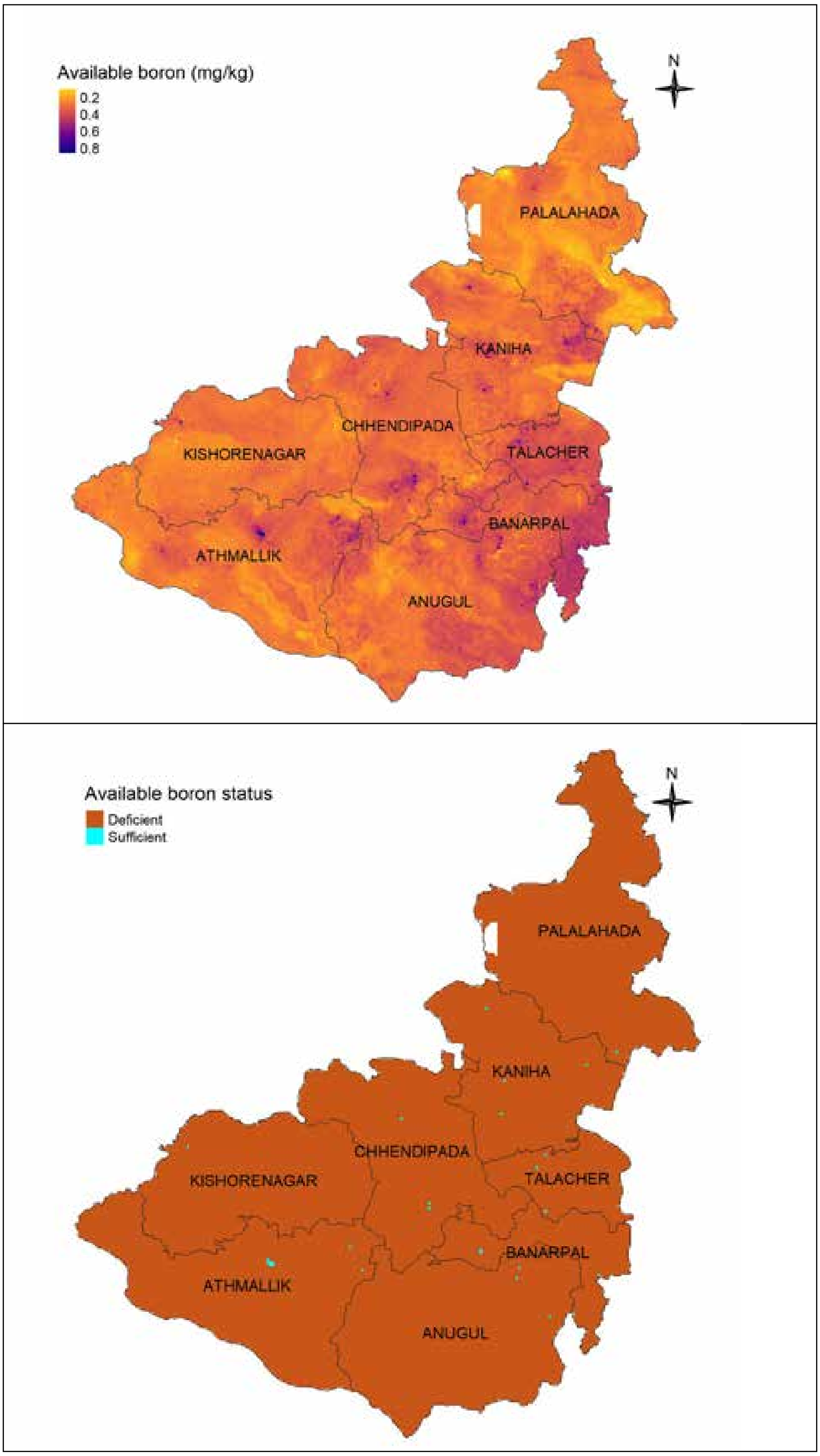


Figure 5.32. Status of available boron in soils of Angul district.

Available Zinc

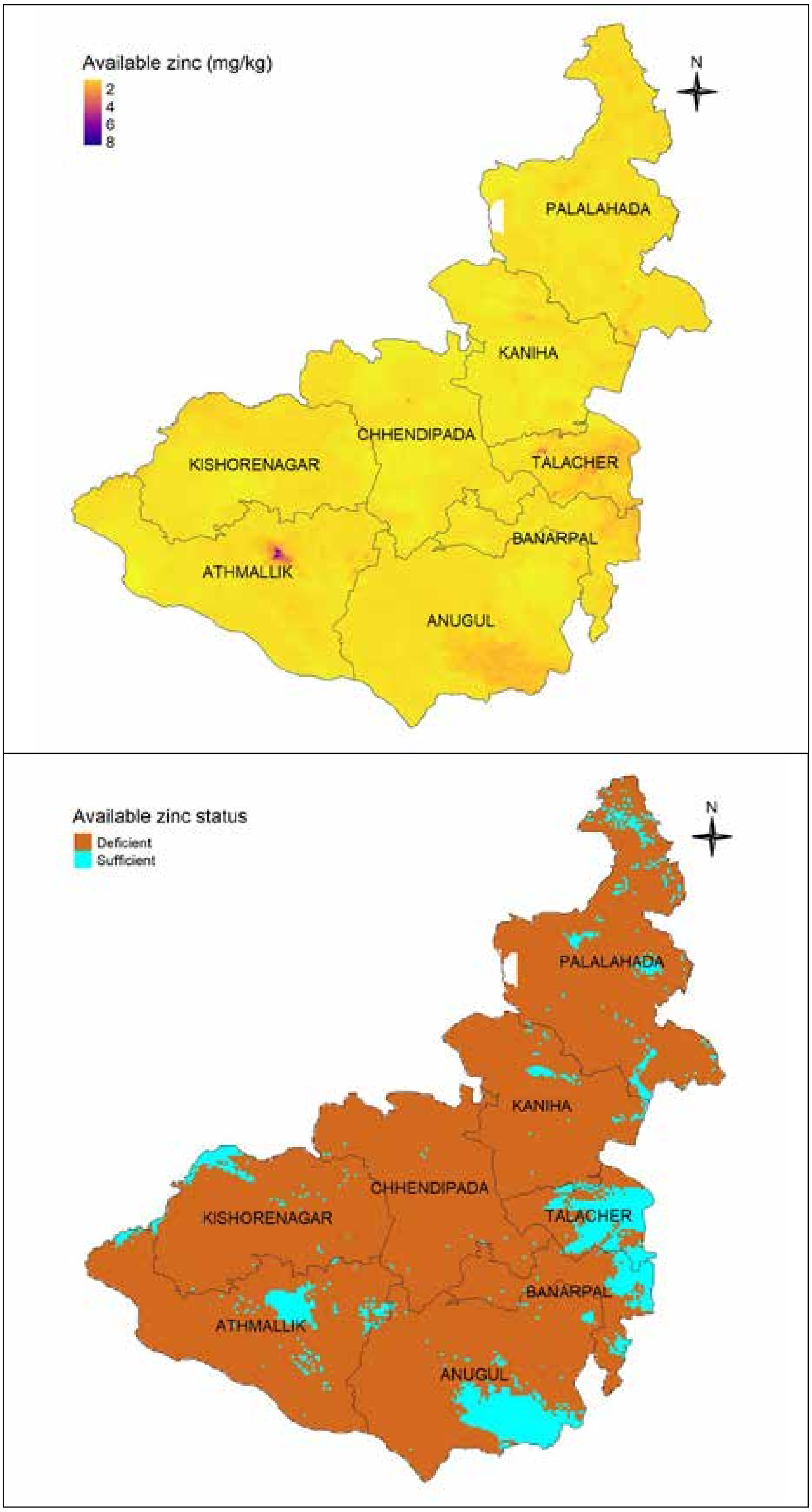


Figure 5.33. Status of available zinc in soils of Angul district.

Balangir | pH

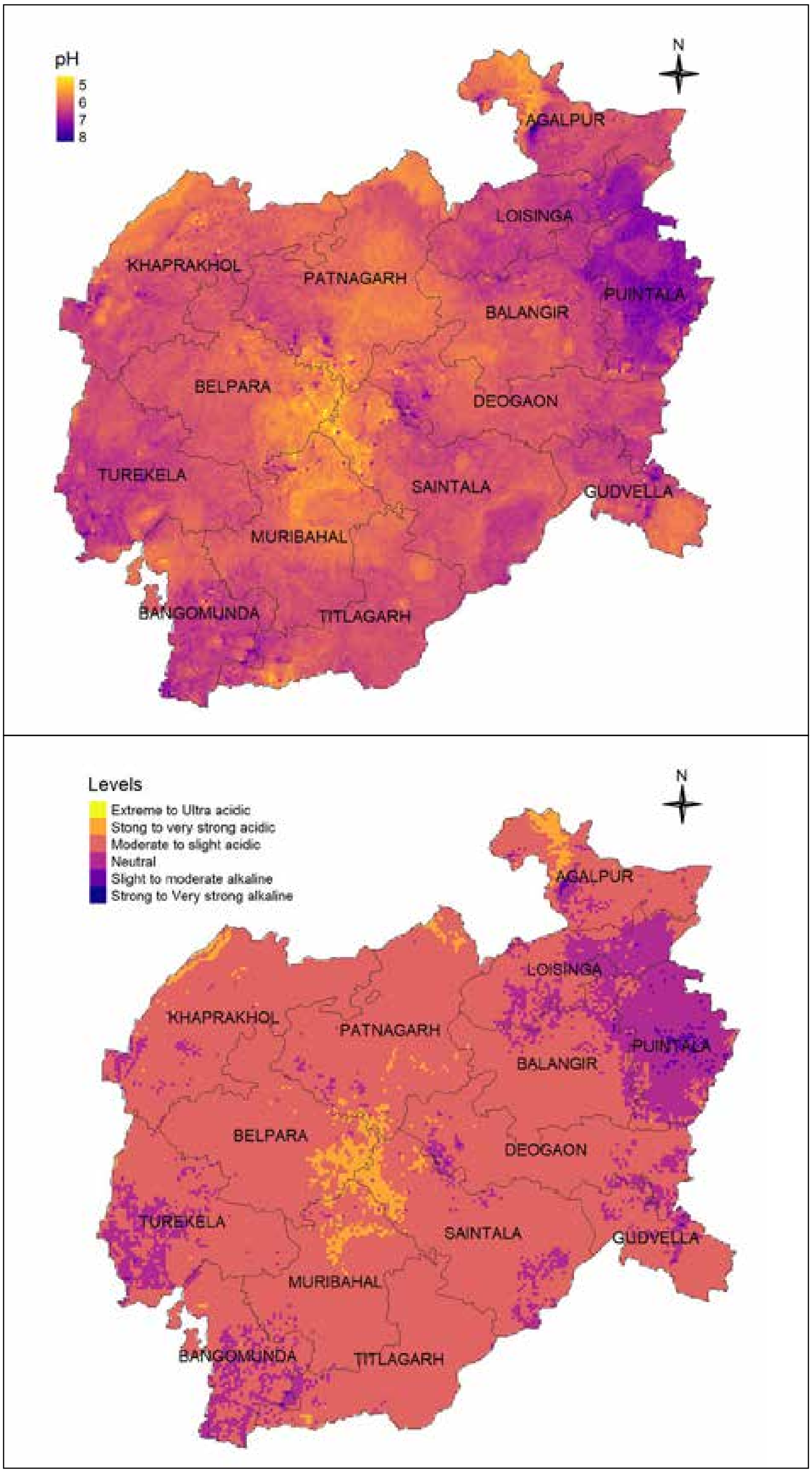


Figure 5.34. pH status in soils of Balangir district.

Electrical conductivity

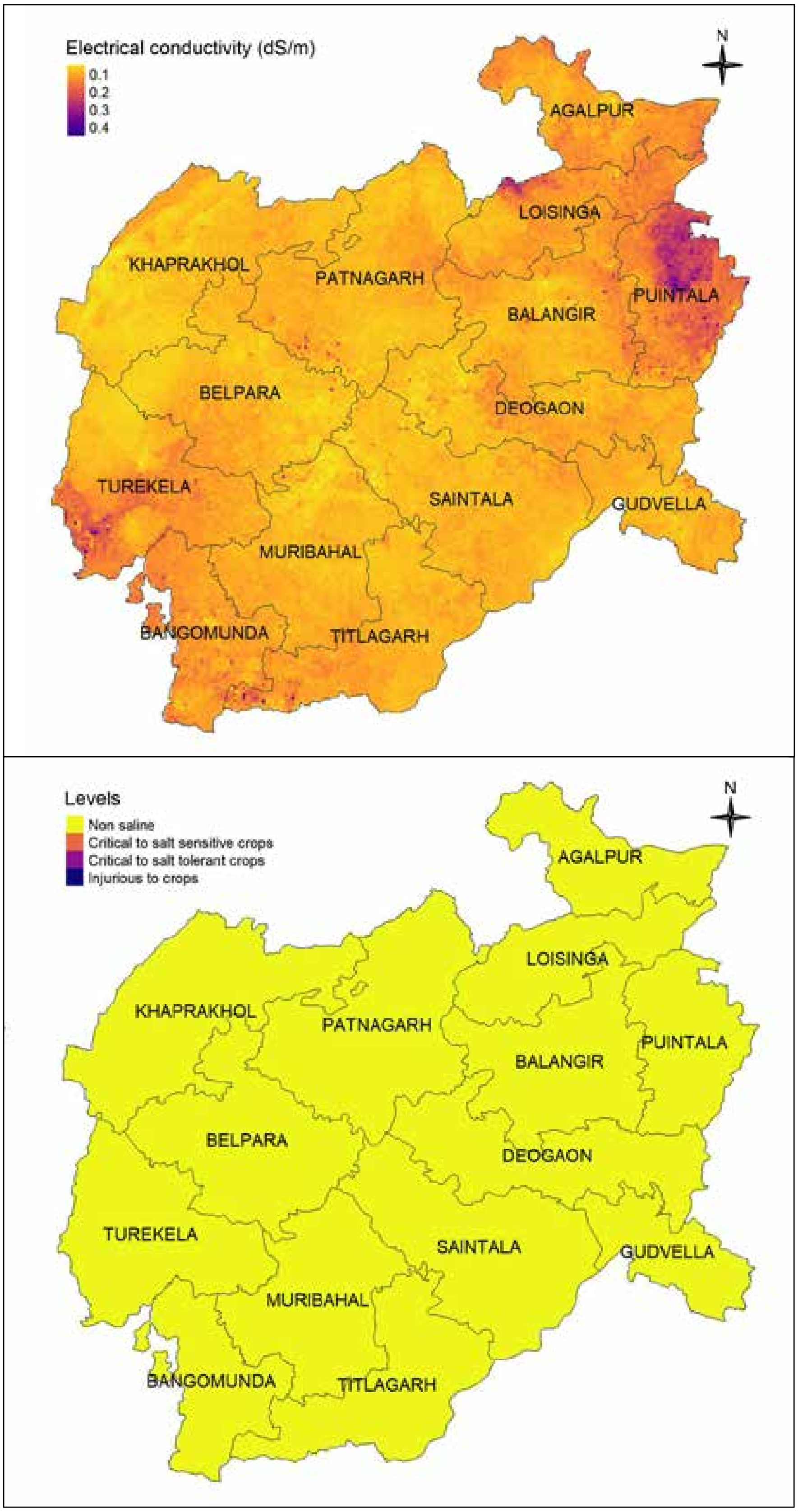


Figure 5.35. Status of electrical conductivity in soils of Balangir district.

Organic carbon

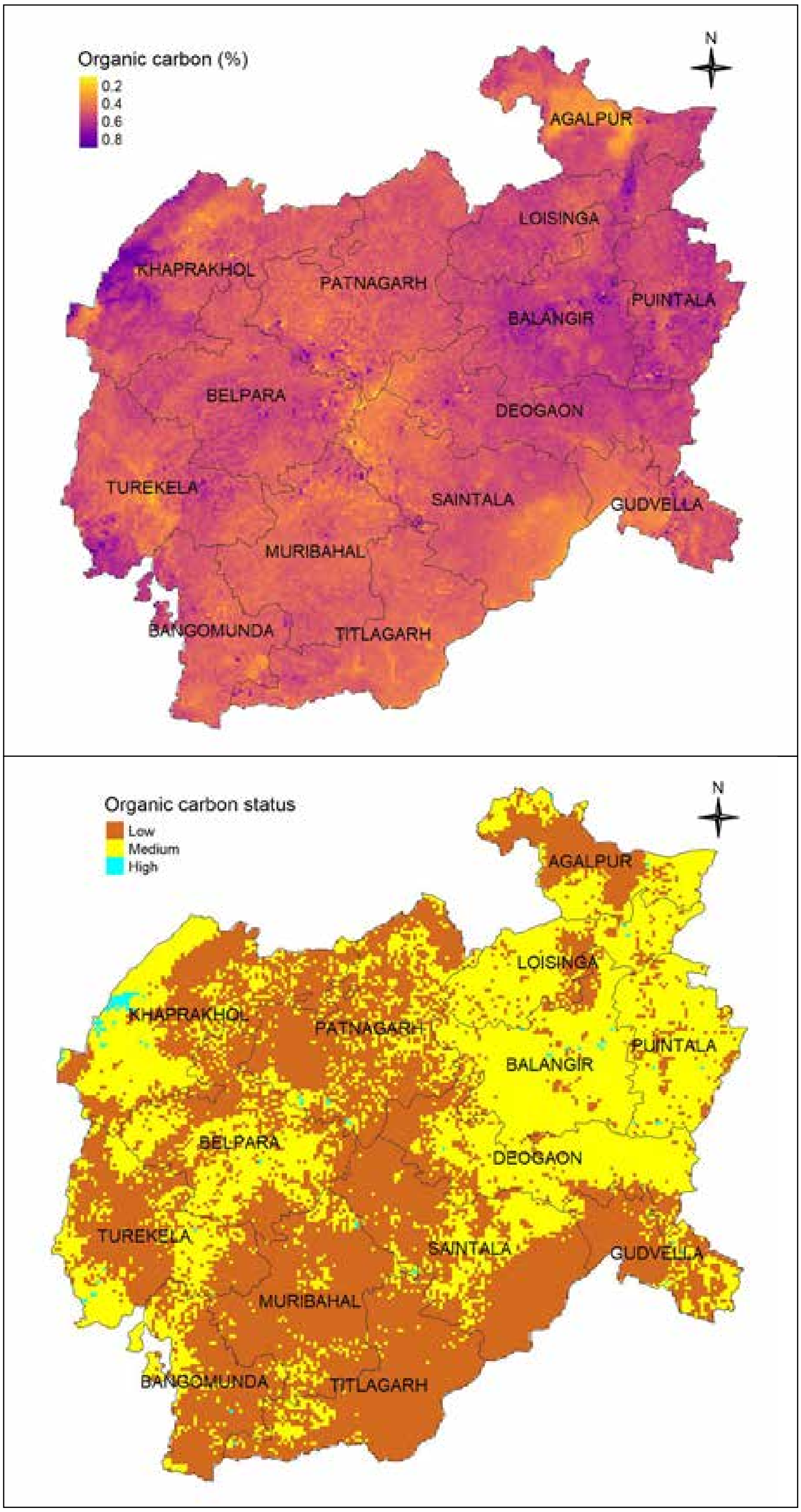


Figure 5.36. Organic carbon status in soils of Balangir district.

Available Phosphorous

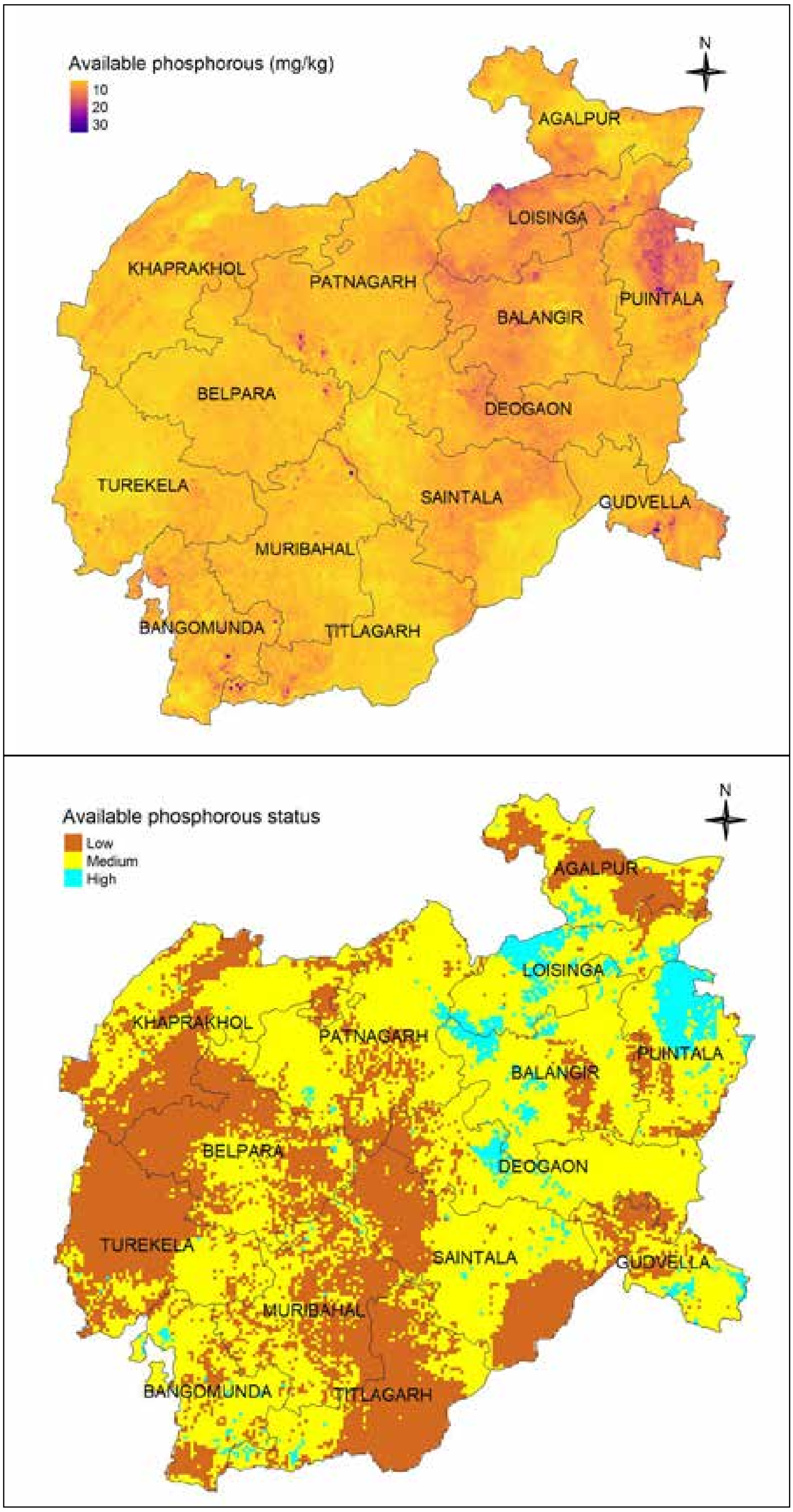


Figure 5.37. Status of available phosphorous in soils of Balangir district.

Exchangeable Potassium

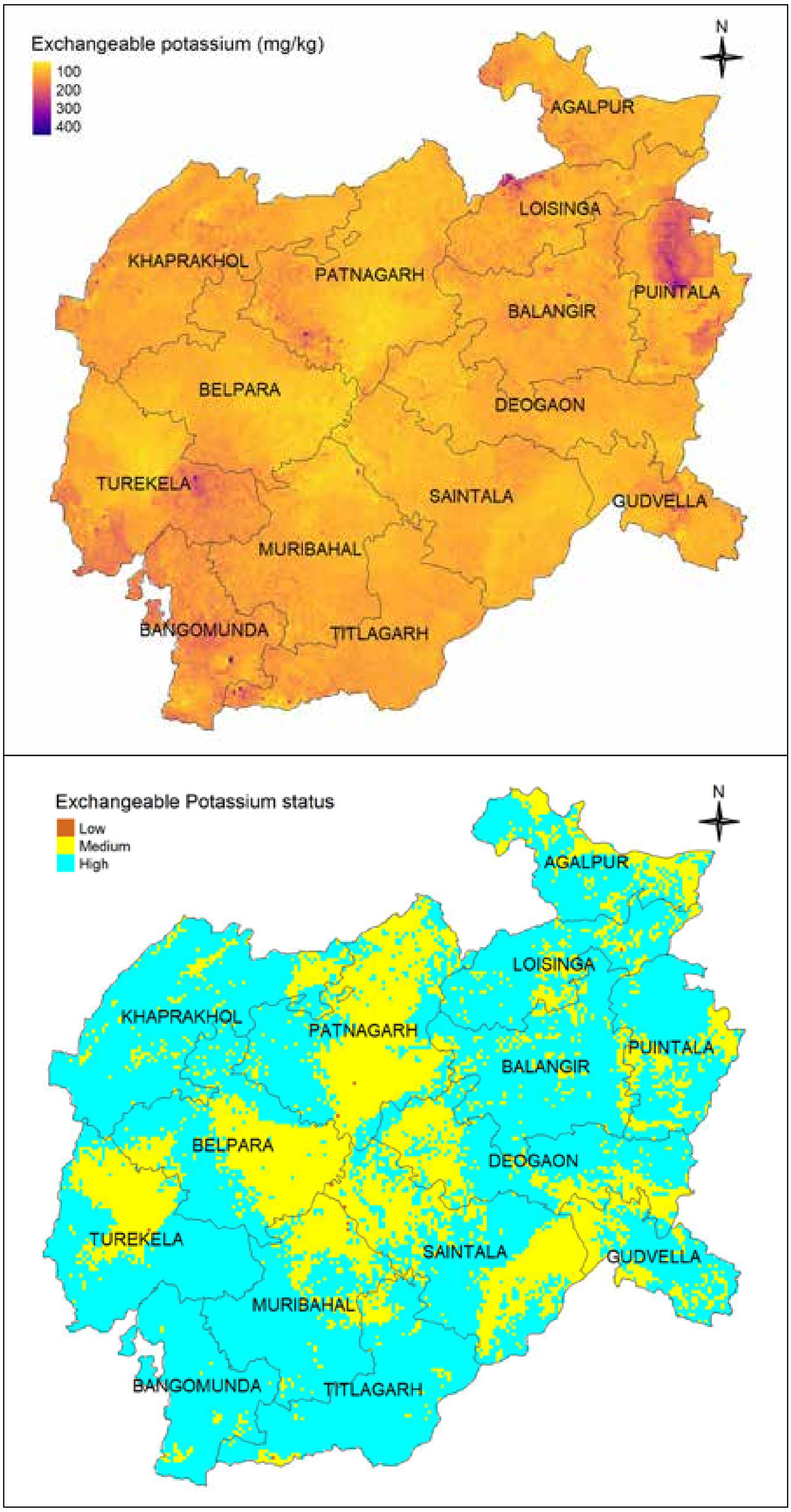


Figure 5.38. Status of exchangeable potassium in soils of Balangir district.

Available Sulfur

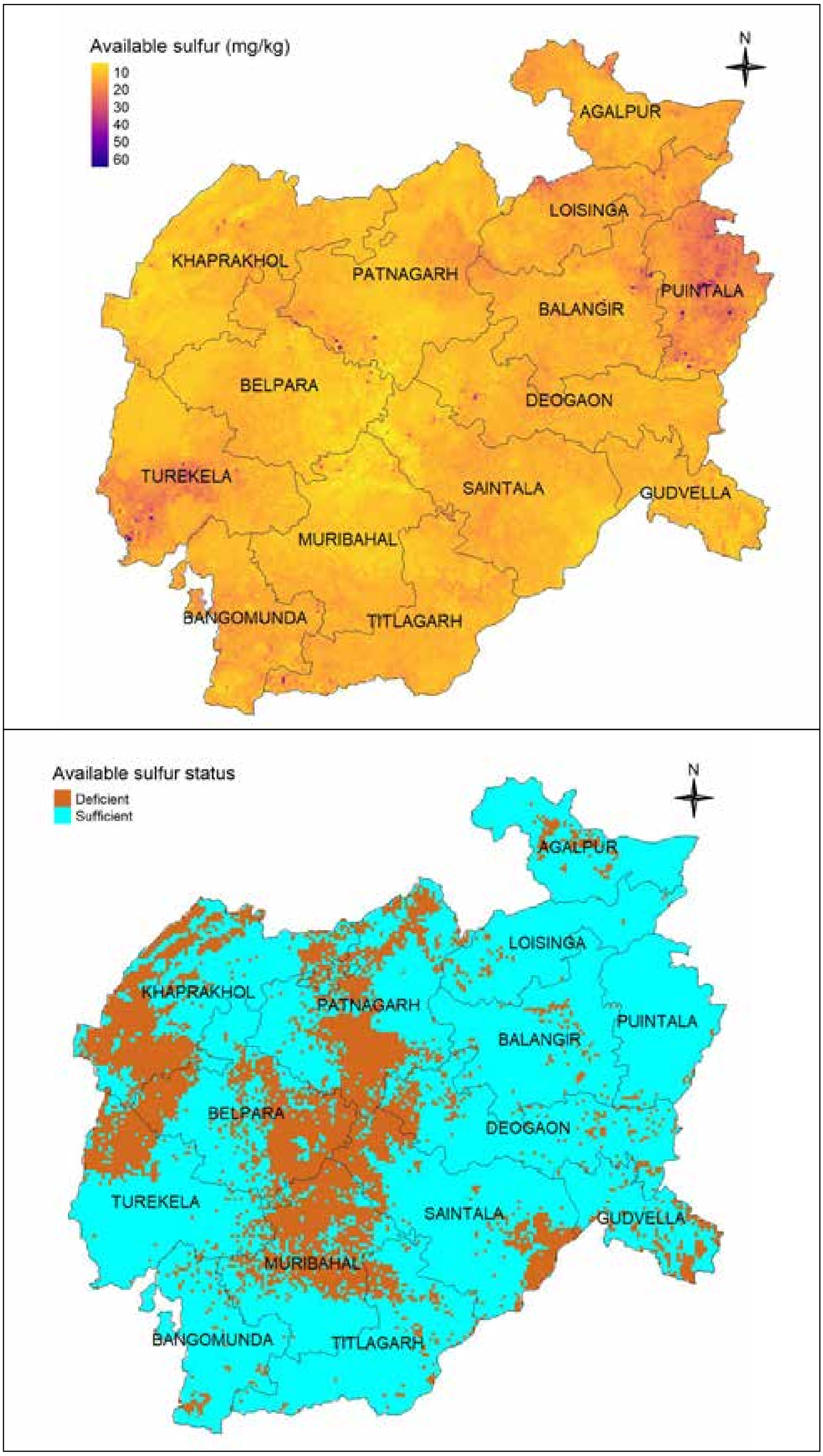


Figure 5.39. Status of available sulfur in soils of Balangir district.

Available Boron

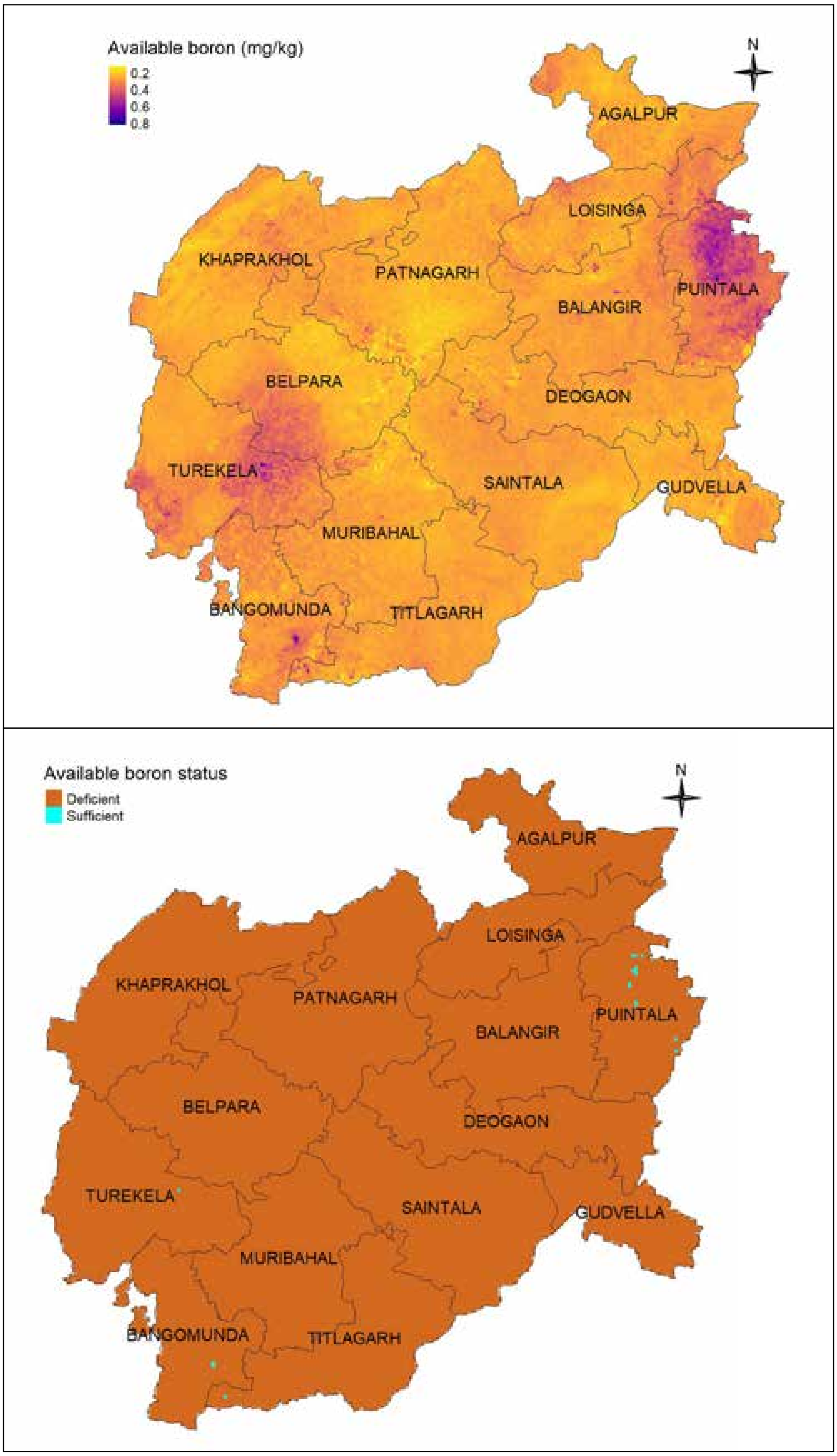


Figure 5.40. Status of available boron in soils of Balangir district.

Available Zinc

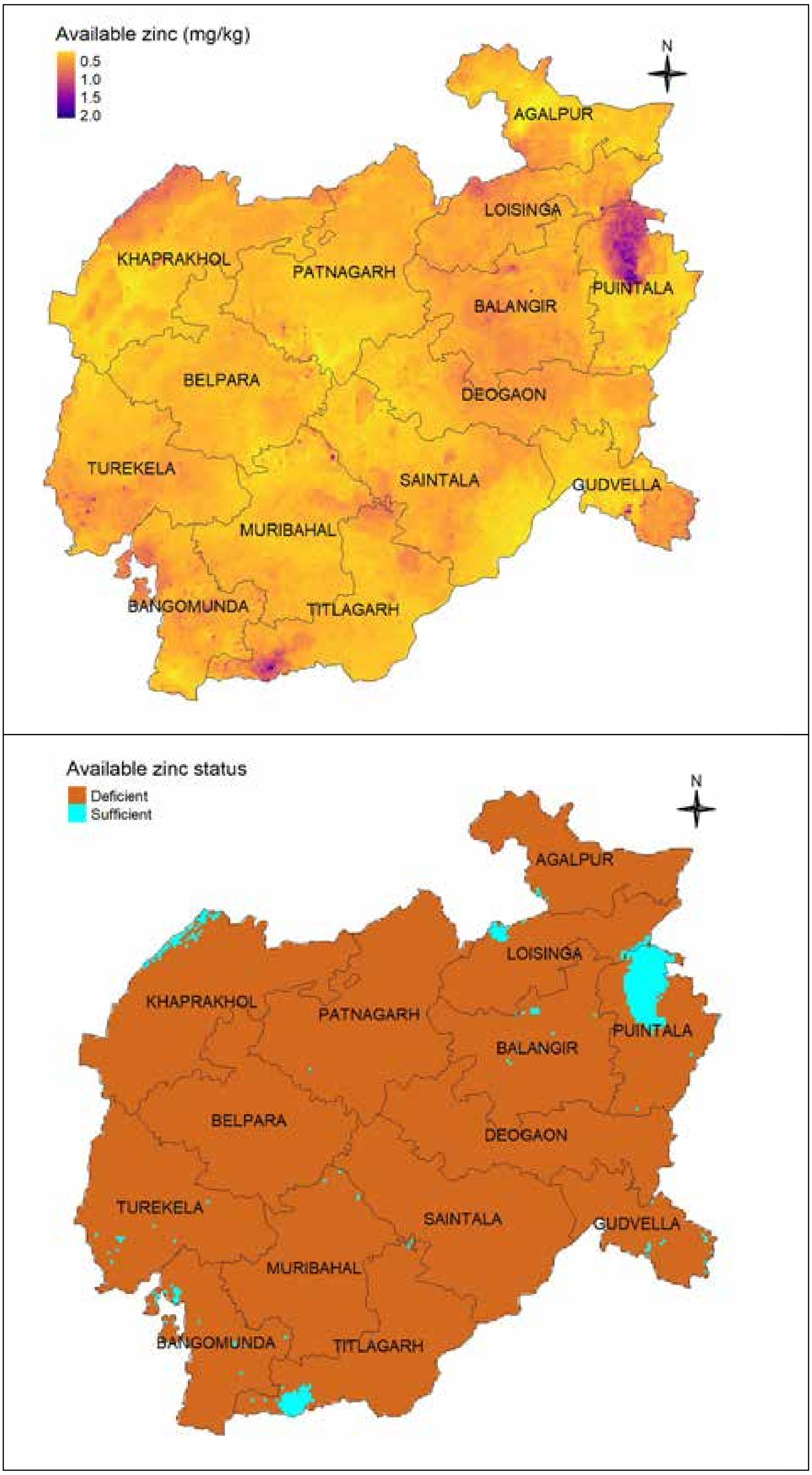


Figure 5.41. Status of available zinc in soils of Balangir district.

Baleswar | pH

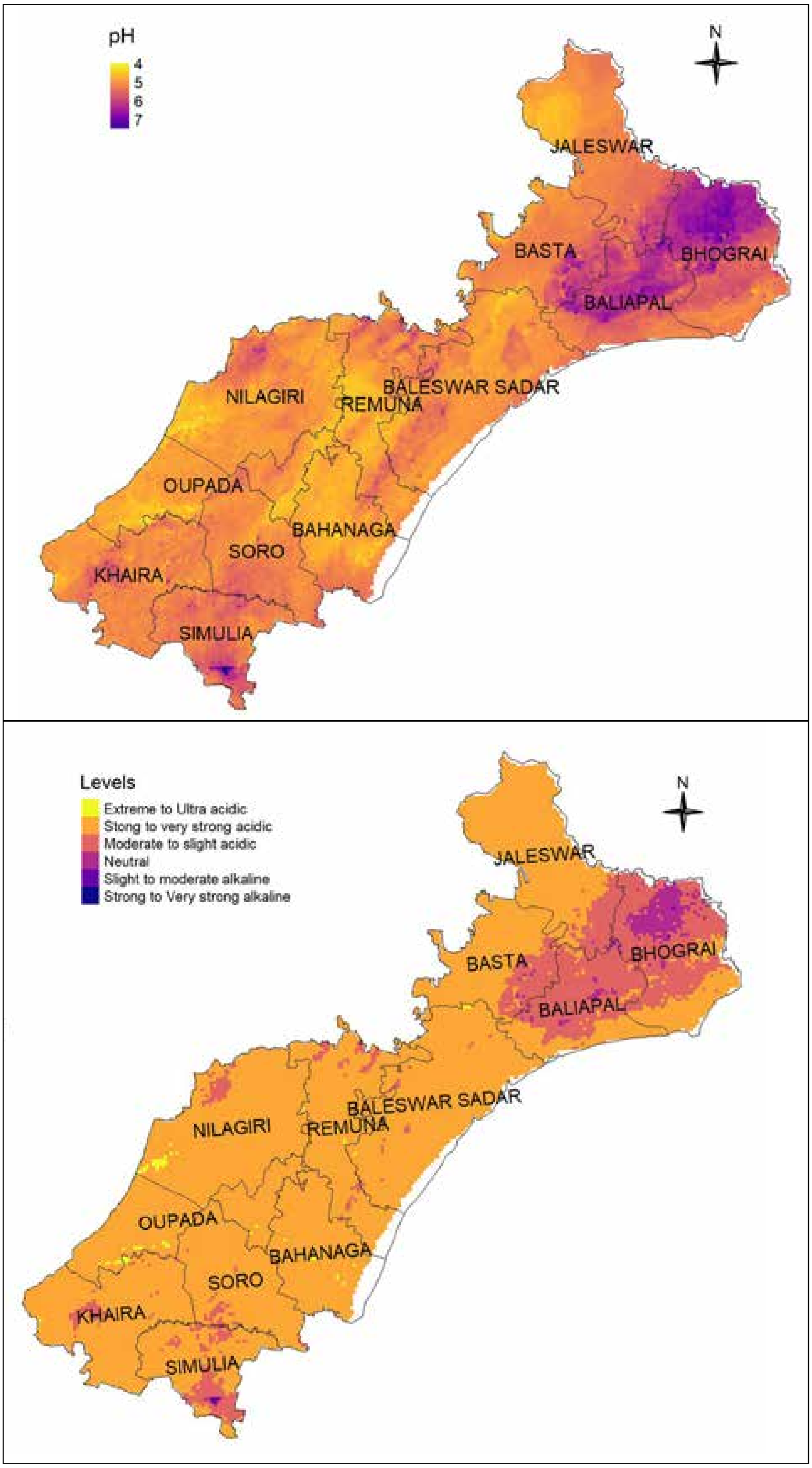


Figure 5.42. pH status in soils of Baleswar district.

Electrical conductivity

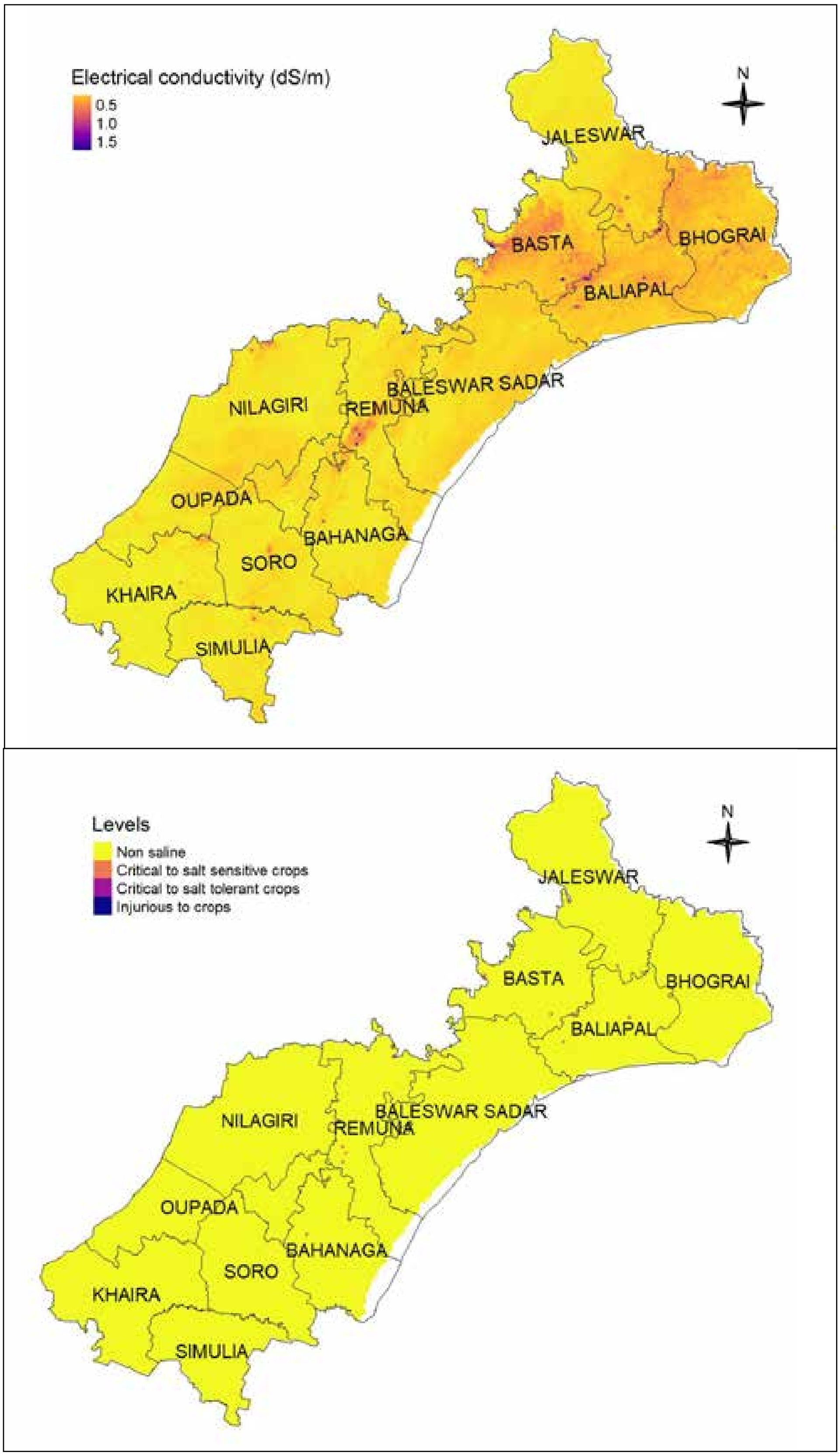


Figure 5.43. Status of electrical conductivity in soils of Baleswar district.

Organic carbon

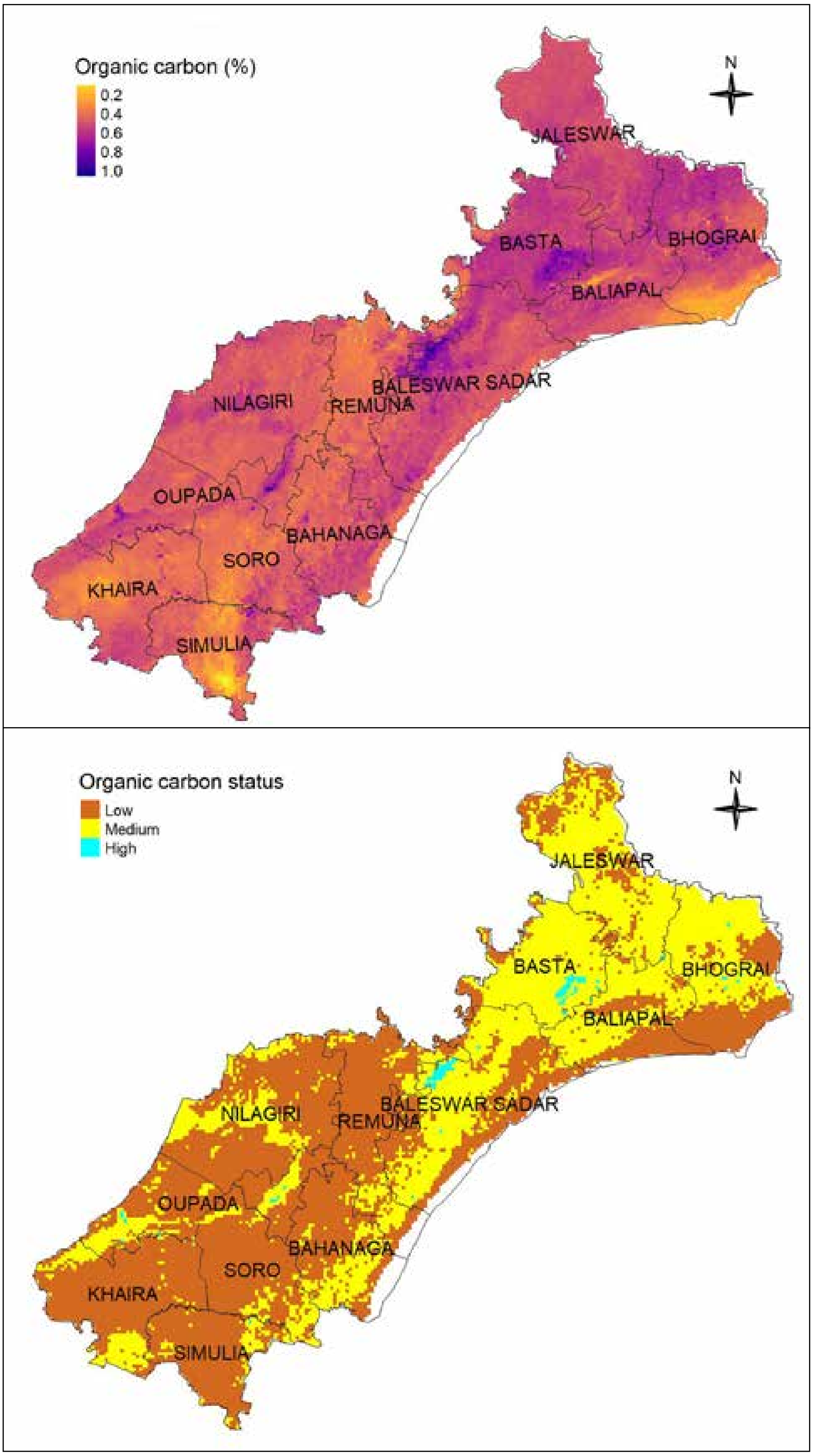


Figure 5.44. Organic carbon status in soils of Baleswar district.

Available Phosphorous

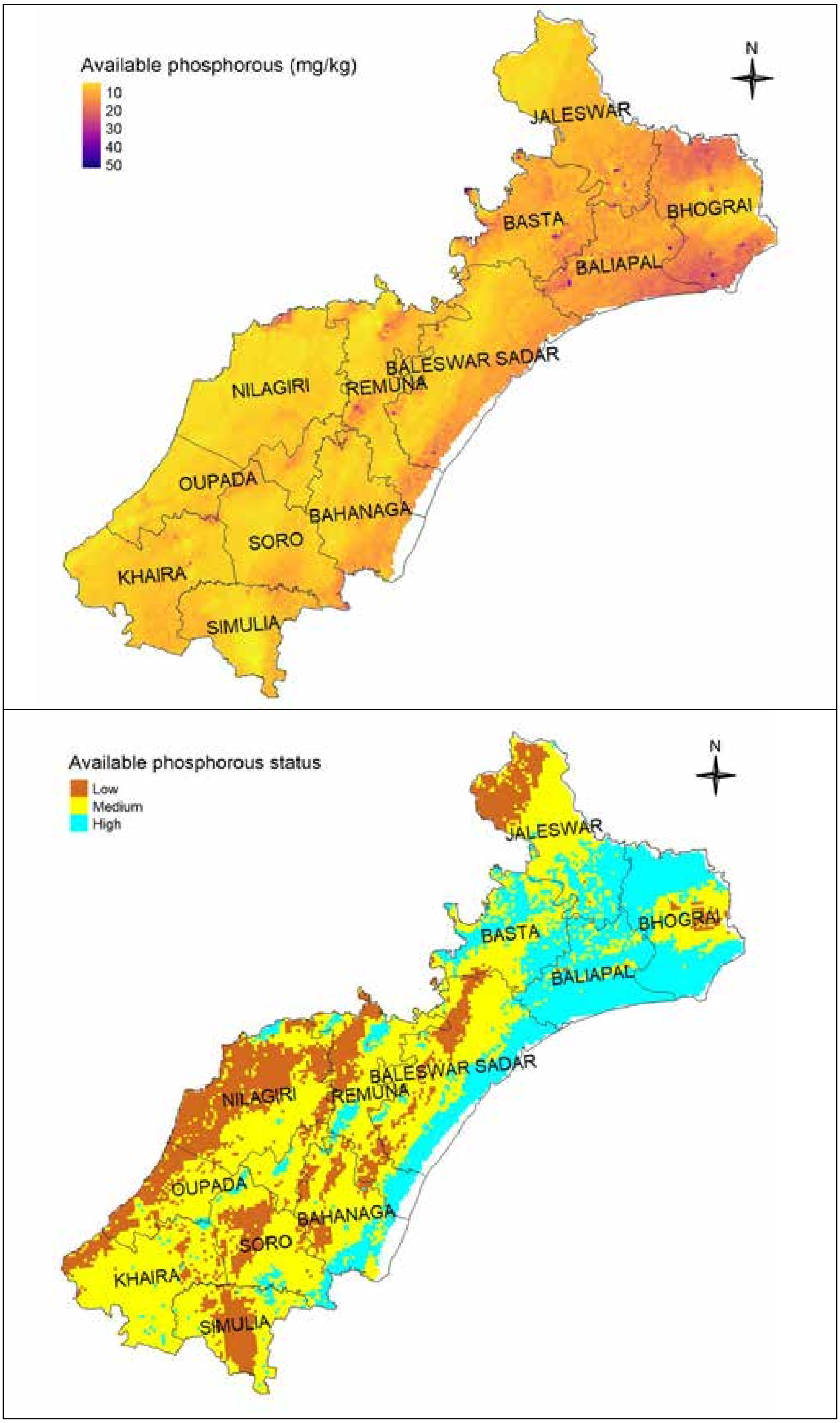


Figure 5.45. Status of available phosphorous in soils of Baleswar district.

Exchangeable Potassium

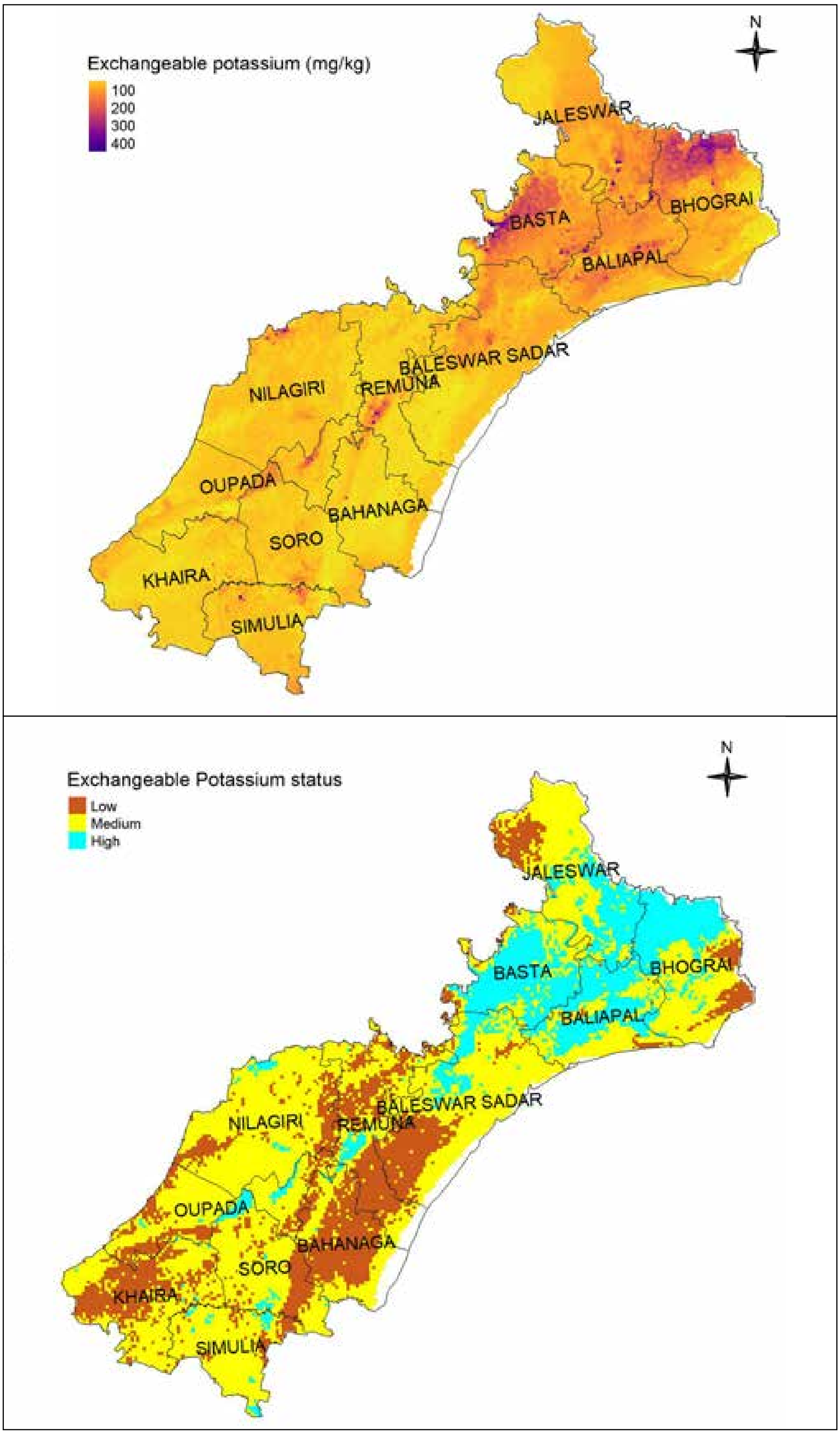


Figure 5.46. Status of exchangeable potassium in soils of Baleswar district.

Available Sulfur

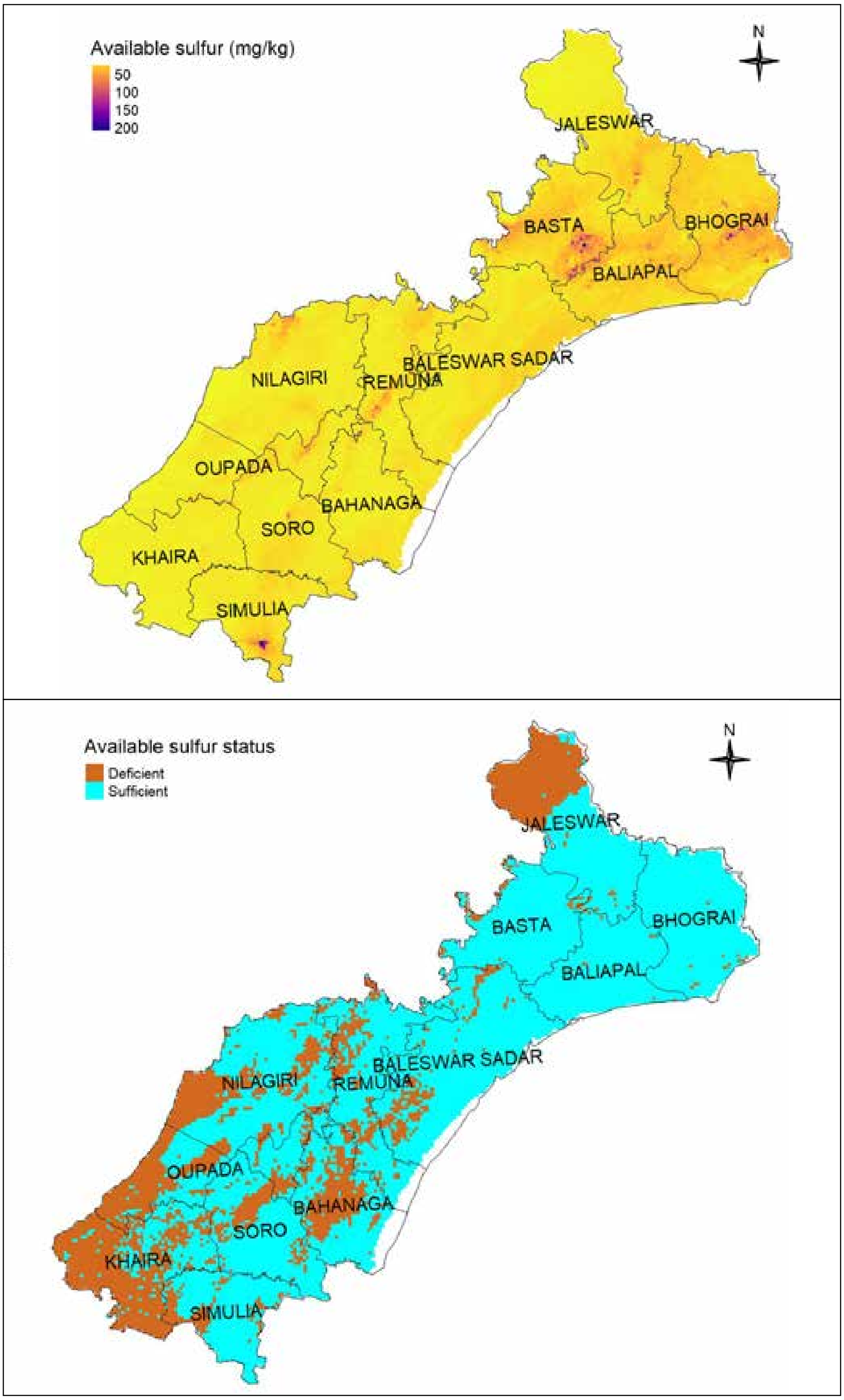


Figure 5.47. Status of available sulfur in soils of Baleswar district.

Available Boron

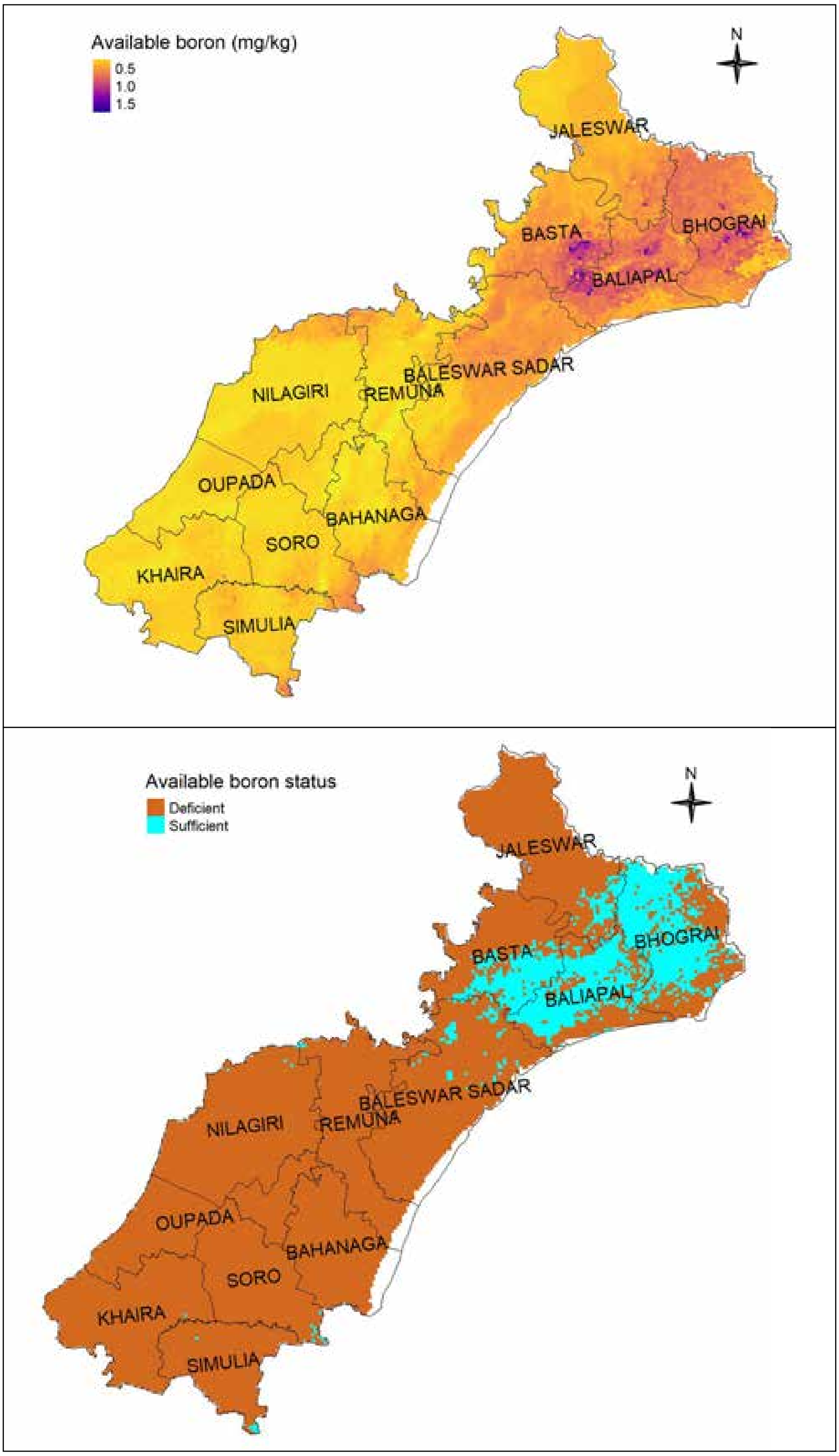


Figure 5.48. Status of available boron in soils of Baleswar district.

Available Zinc

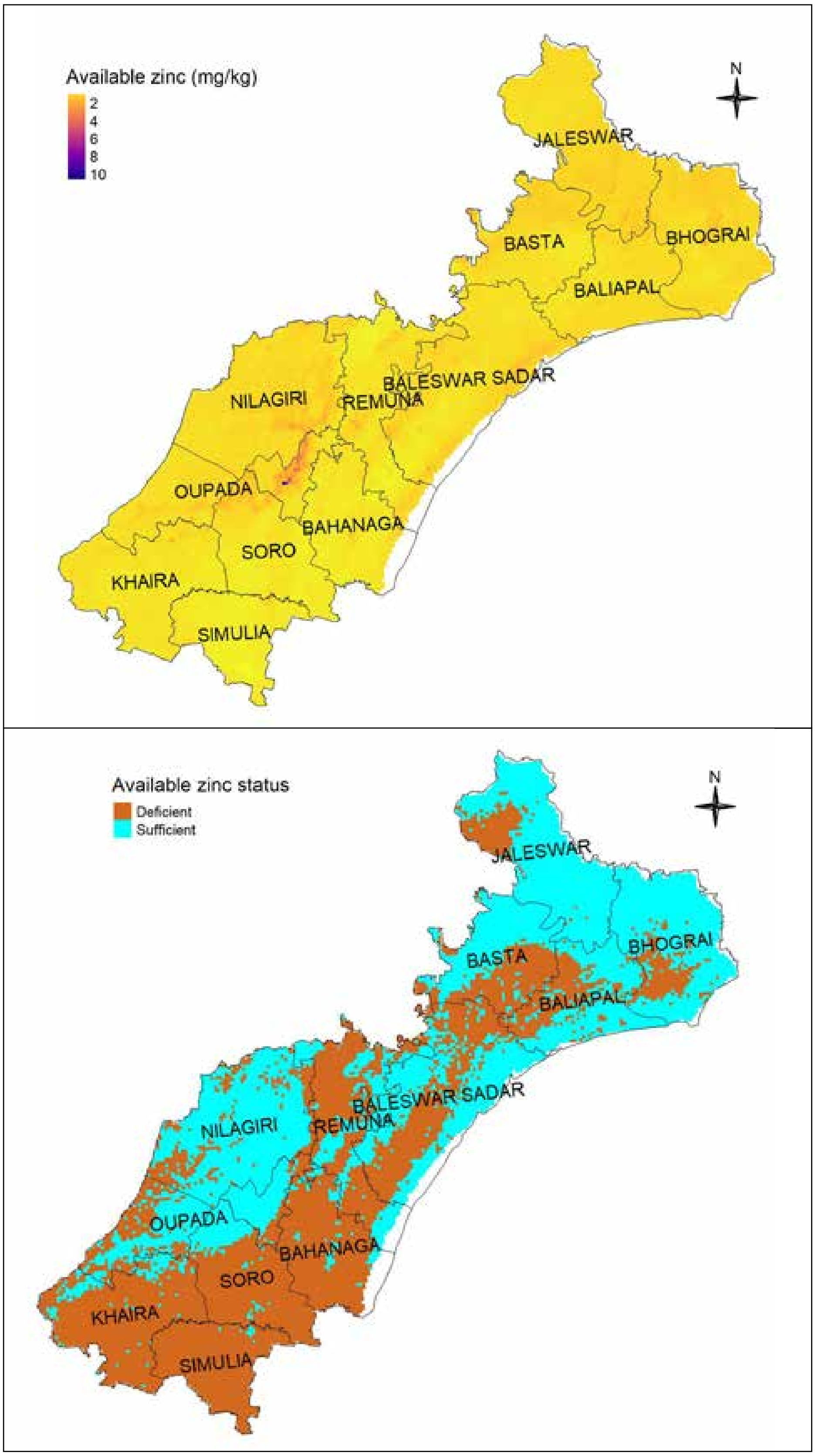


Figure 5.49. Status of available zinc in soils of Baleswar district.

Bargarh | pH

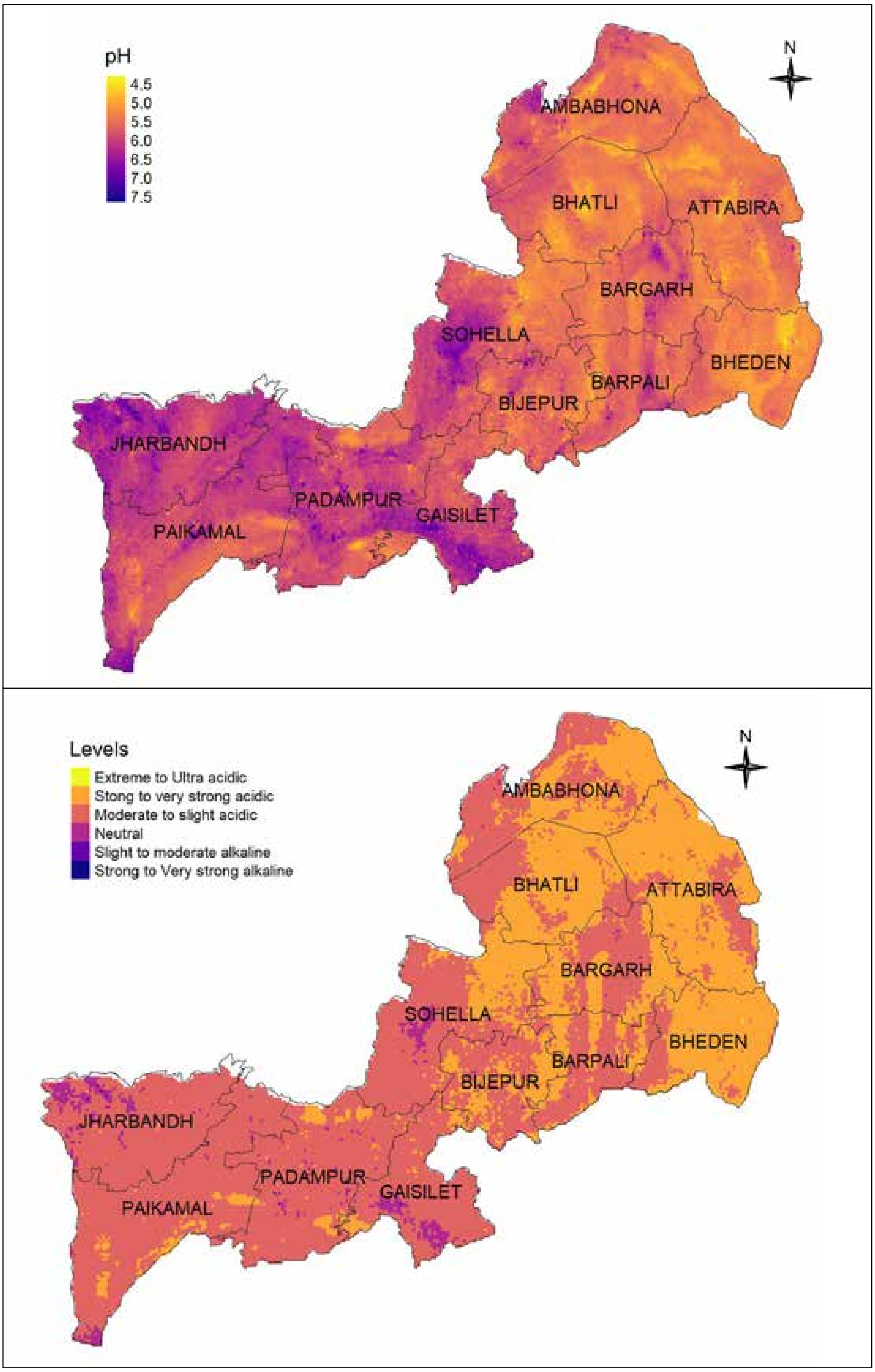


Figure 5.50. pH status in soils of Bargarh district.

Electrical conductivity

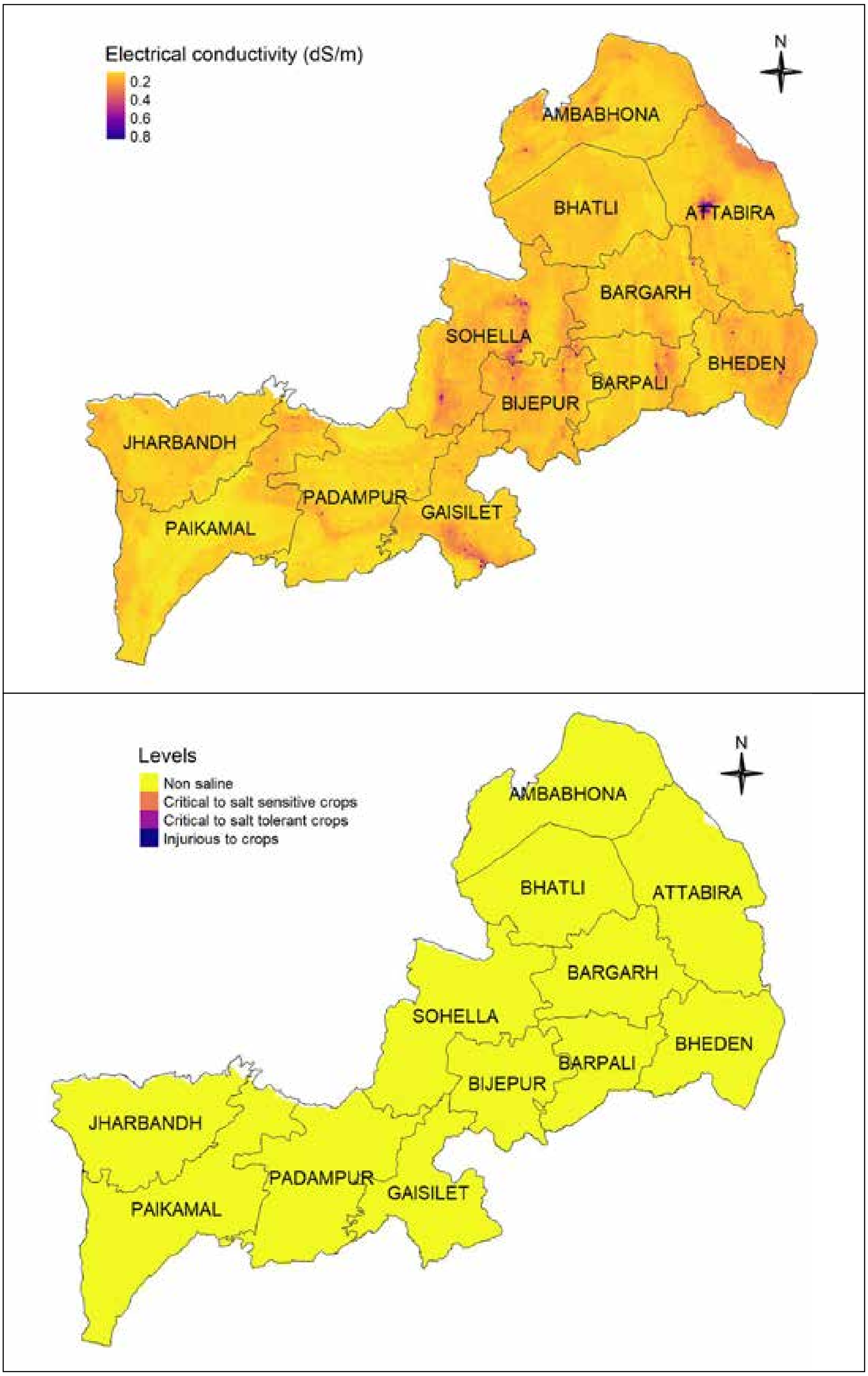


Figure 5.51. Status of electrical conductivity in soils of Bargarh district.

Organic carbon

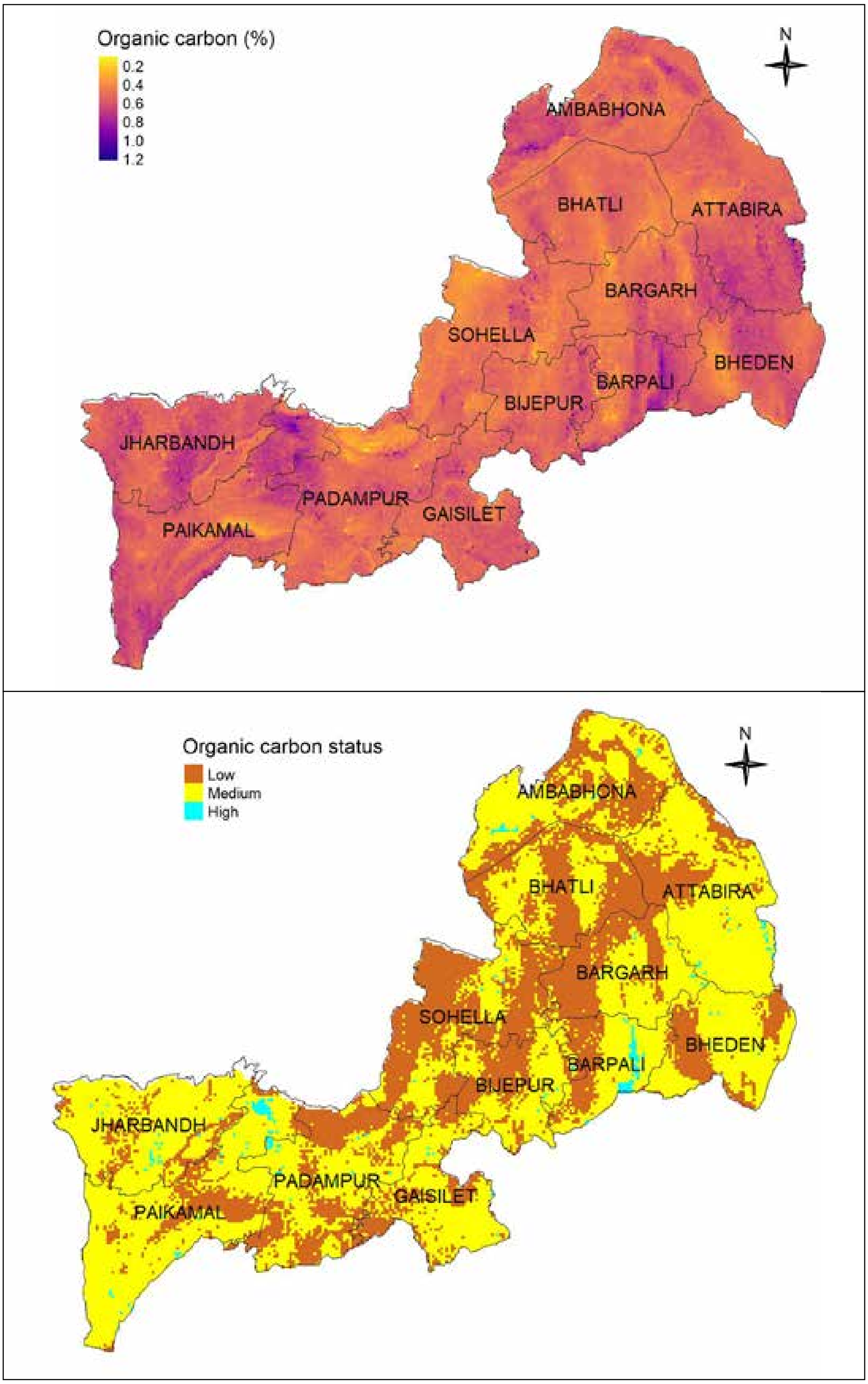


Figure 5.52. Organic carbon status in soils of Bargarh district.

Available Phosphorous

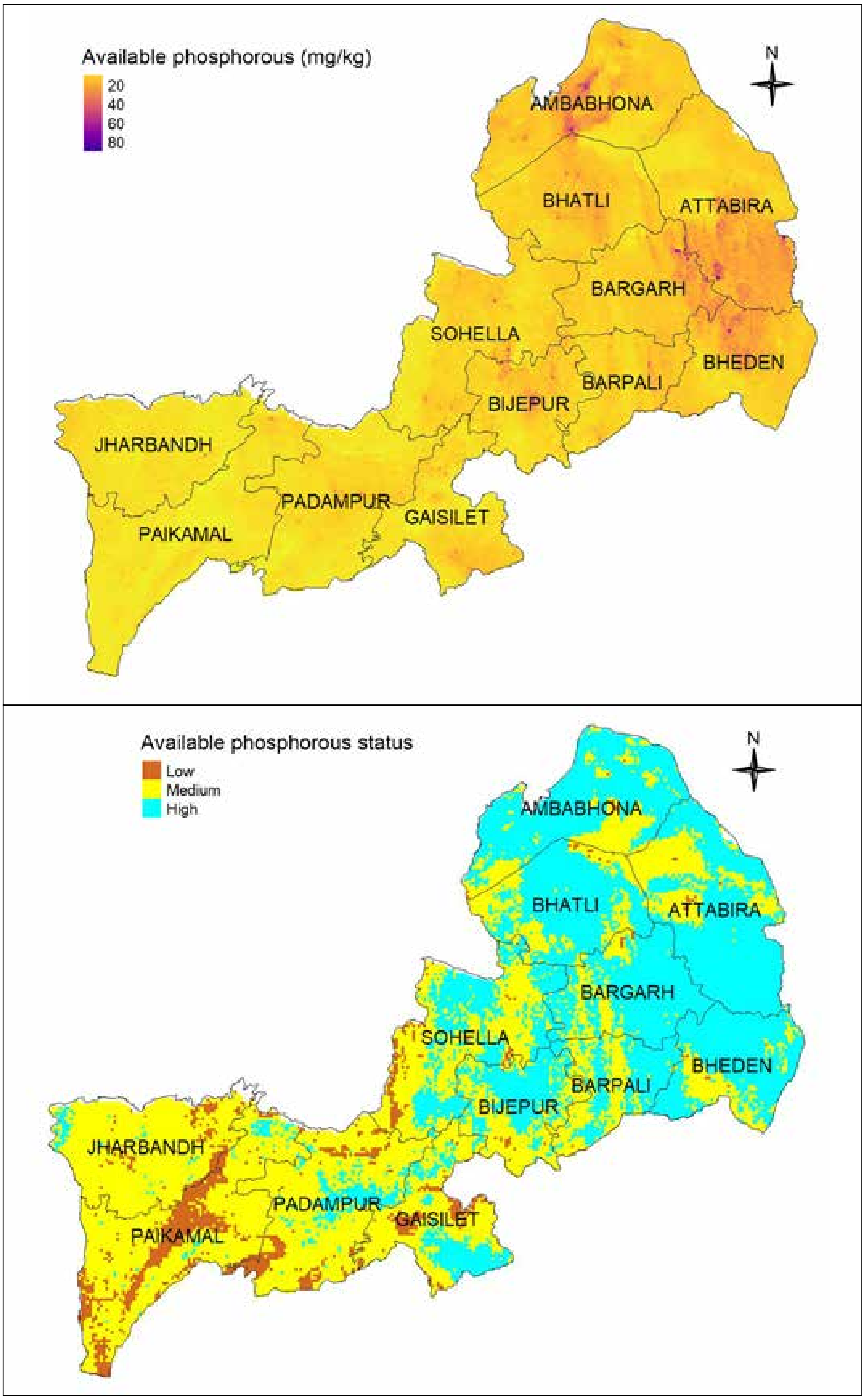


Figure 5.53. Status of available phosphorous in soils of Bargarh district.

Exchangeable Potassium

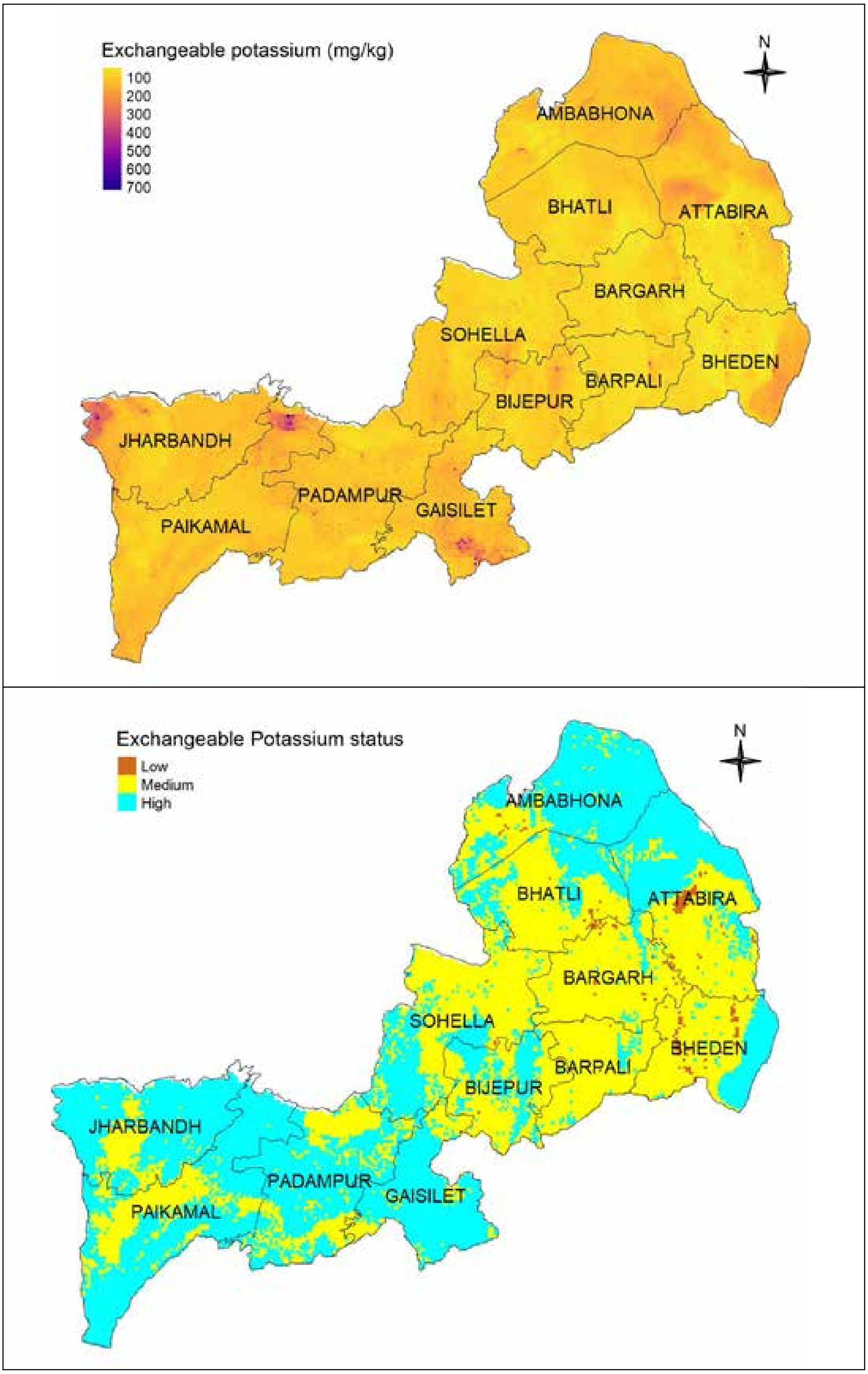


Figure 5.54. Status of exchangeable potassium in soils of Bargarh district.

Available Sulfur

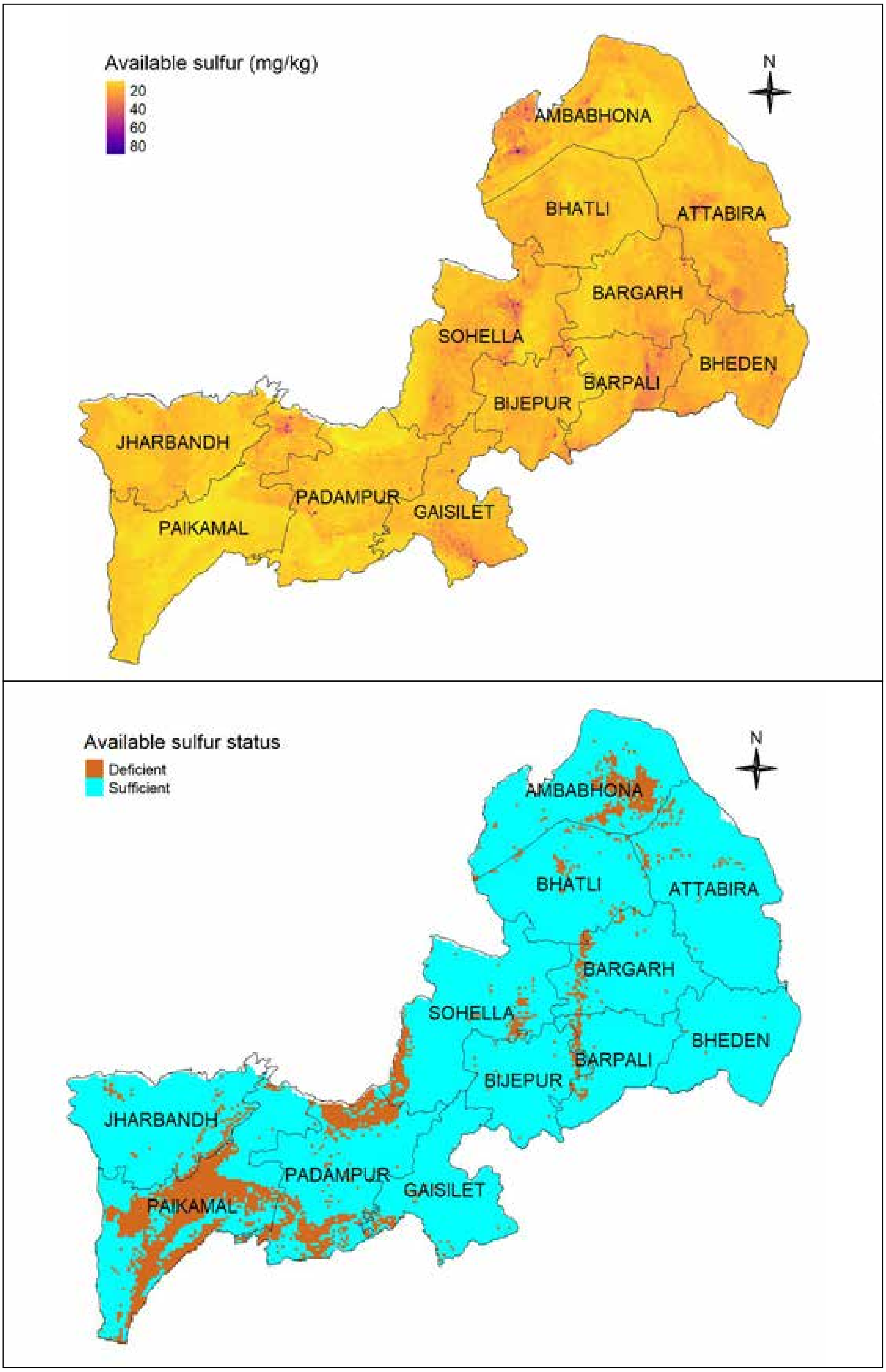


Figure 5.55. Status of available sulfur in soils of Bargarh district.

Available Boron

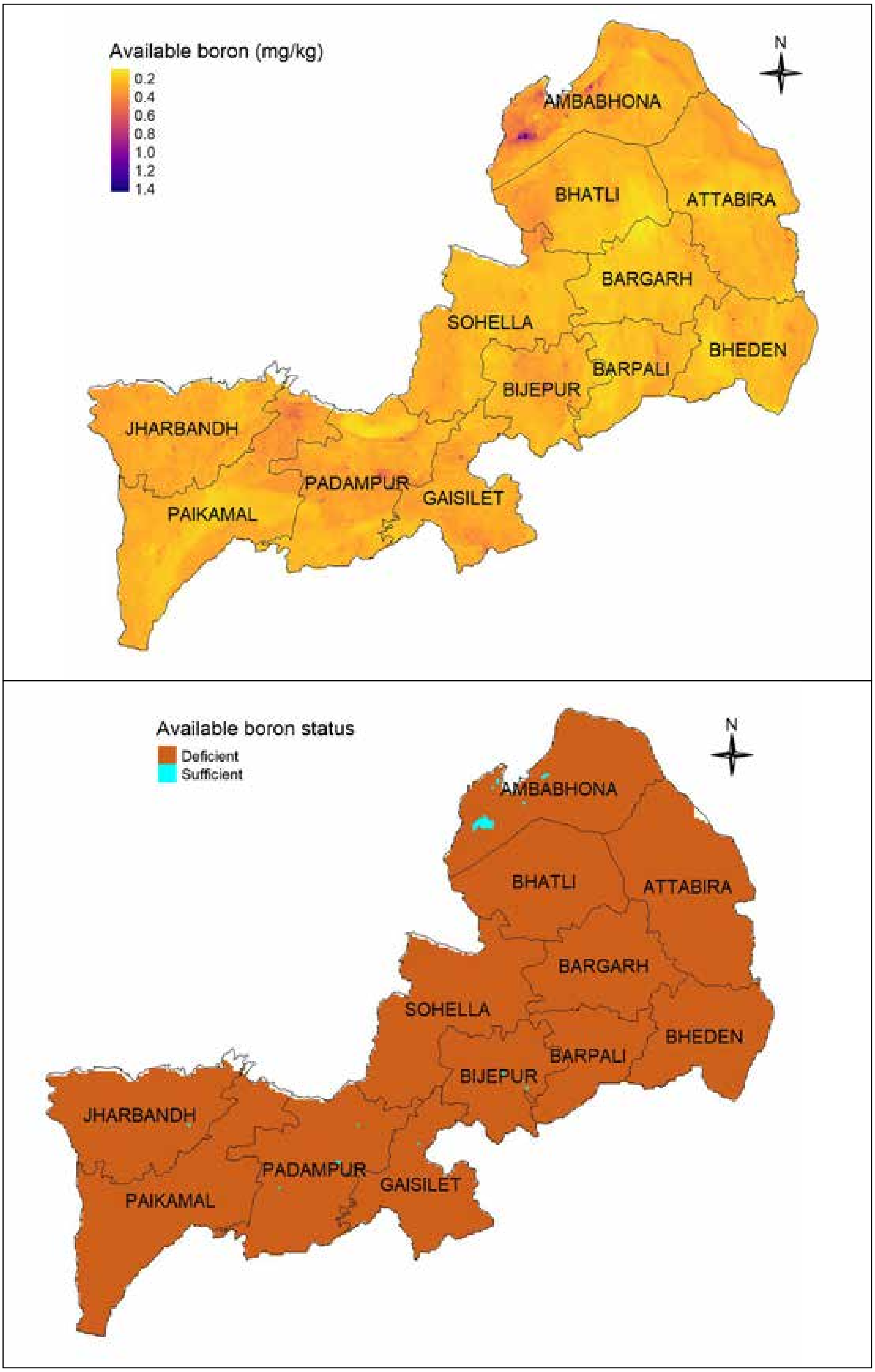


Figure 5.56. Status of available boron in soils of Bargarh district.

Available Zinc

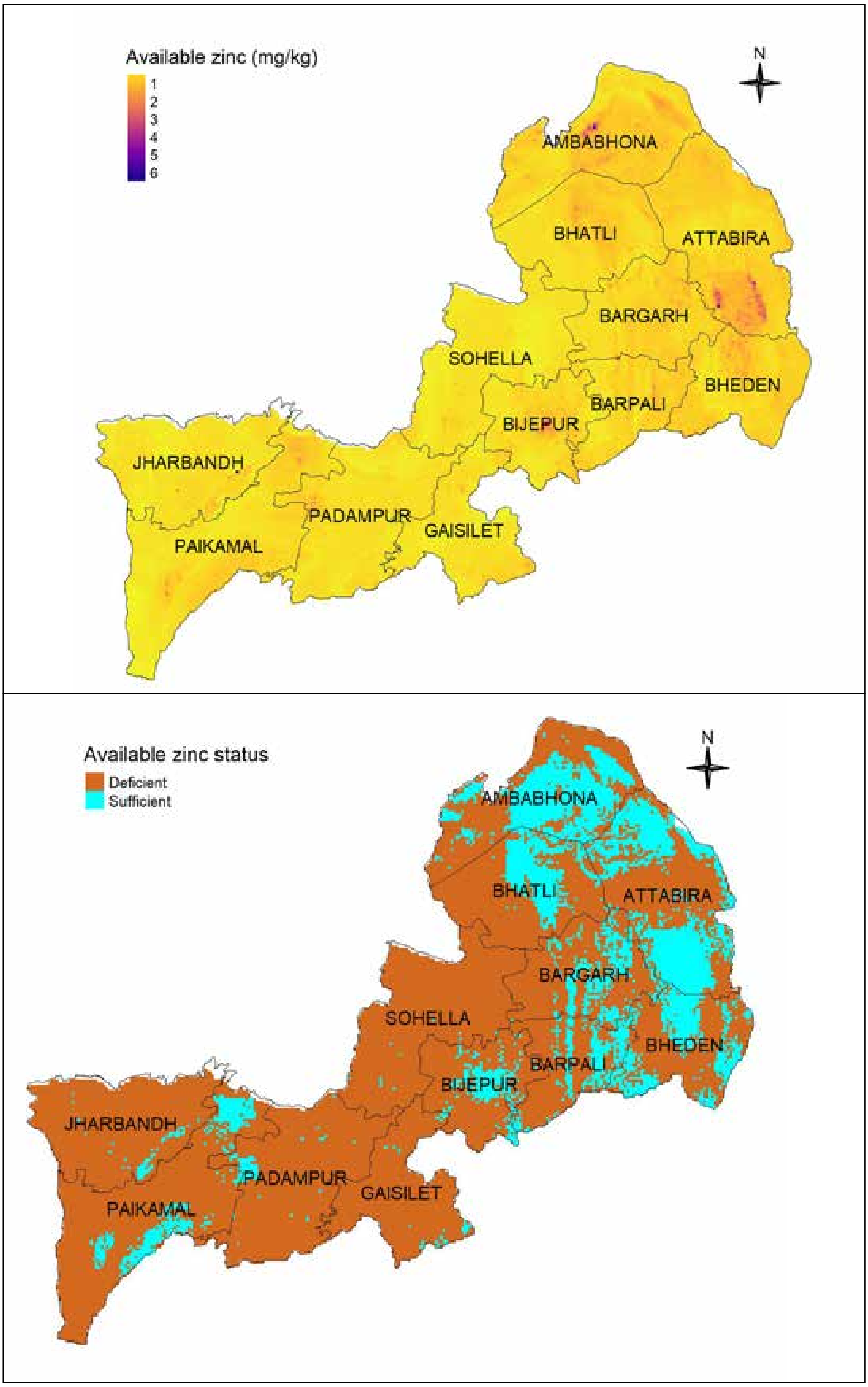


Figure 5.57. Status of available zinc in soils of Bargarh district.

Bhadrak | pH

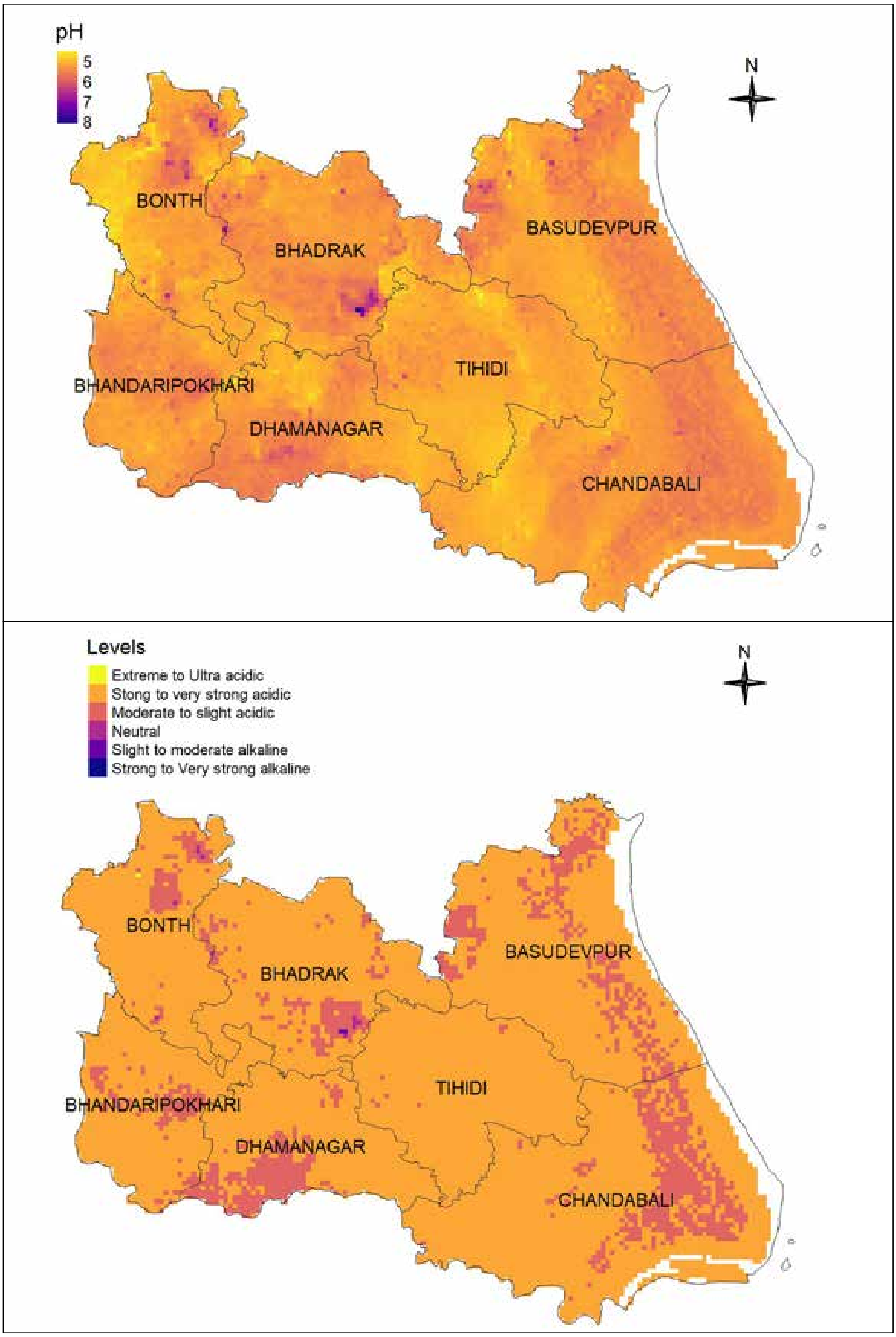


Figure 5.58. pH status in soils of Bhadrak district.

Electrical conductivity

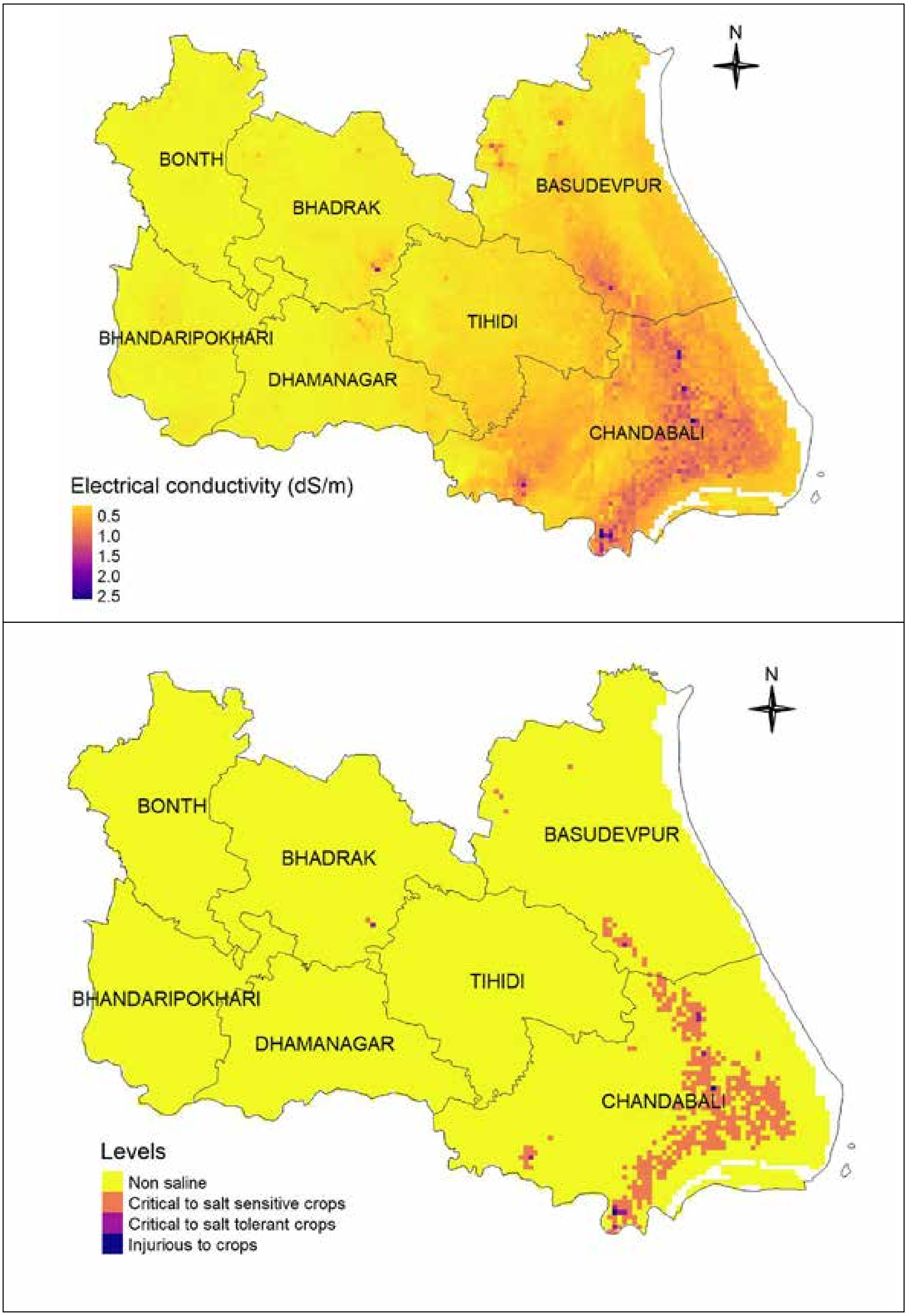


Figure 5.59. Status of electrical conductivity in soils of Bhadrak district.

Organic carbon

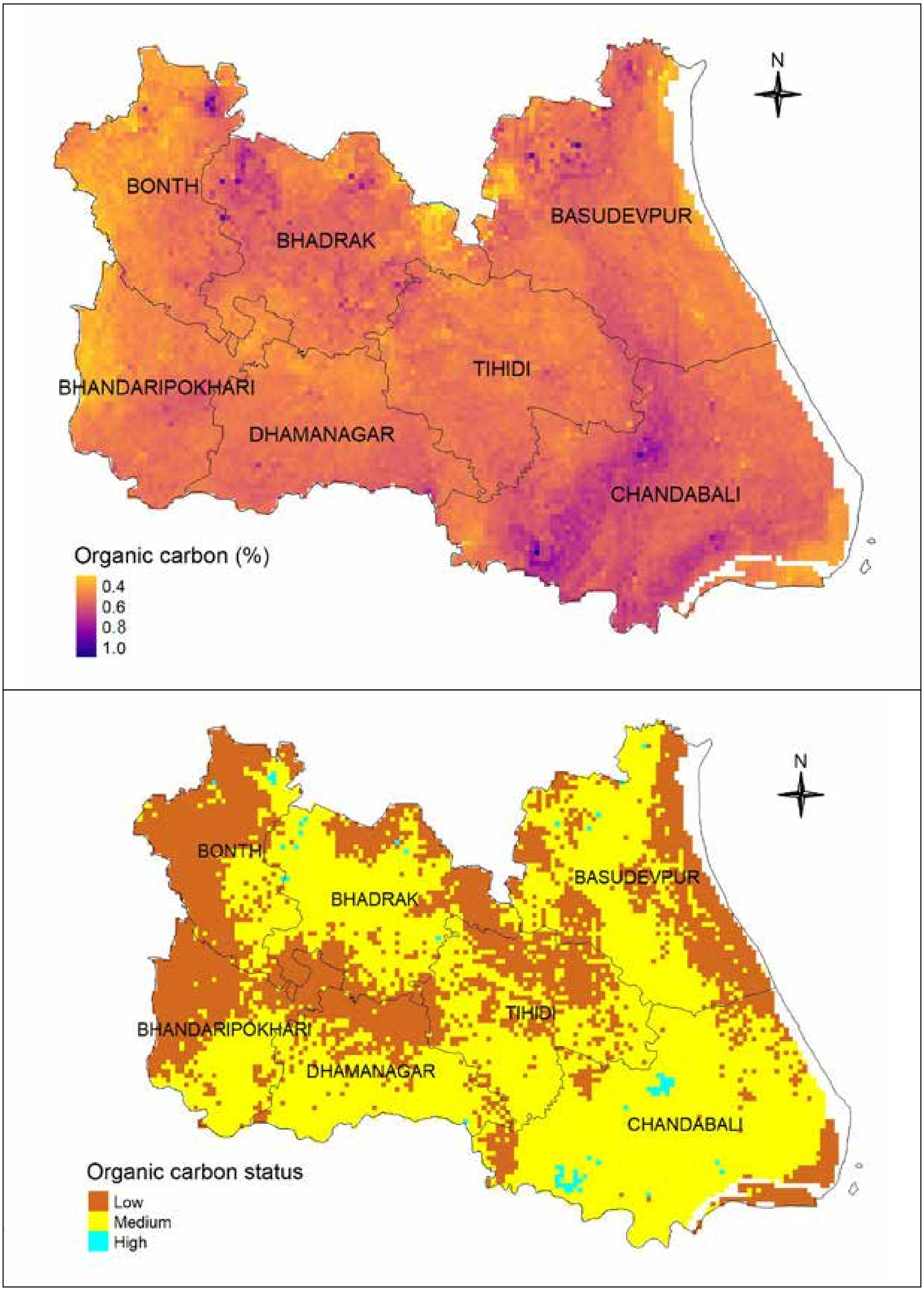


Figure 5.60. Organic carbon status in soils of Bhadrak district.

Available Phosphorous

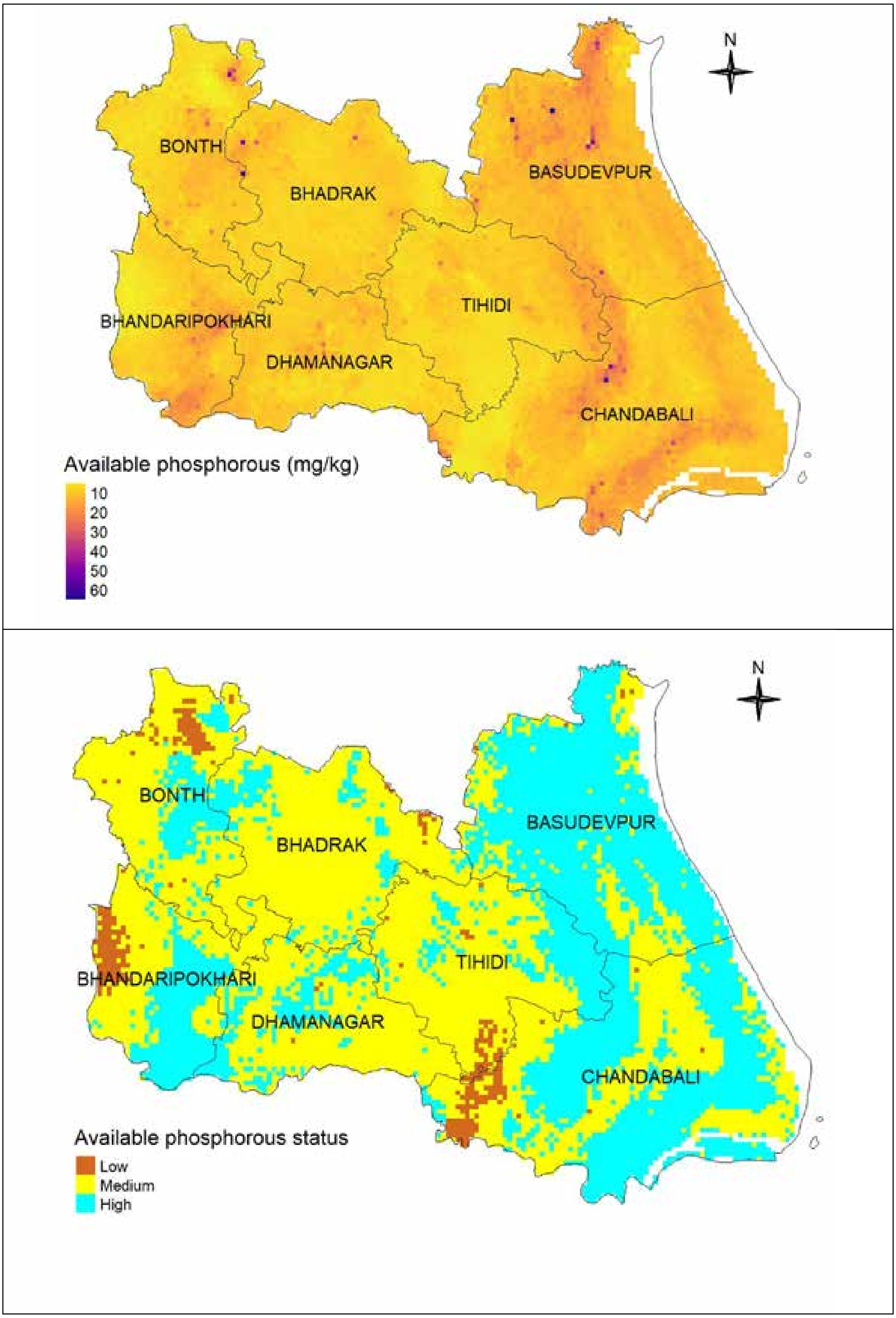


Figure 5.61. Status of available phosphorous in soils of Bhadrak district.

Exchangeable Potassium

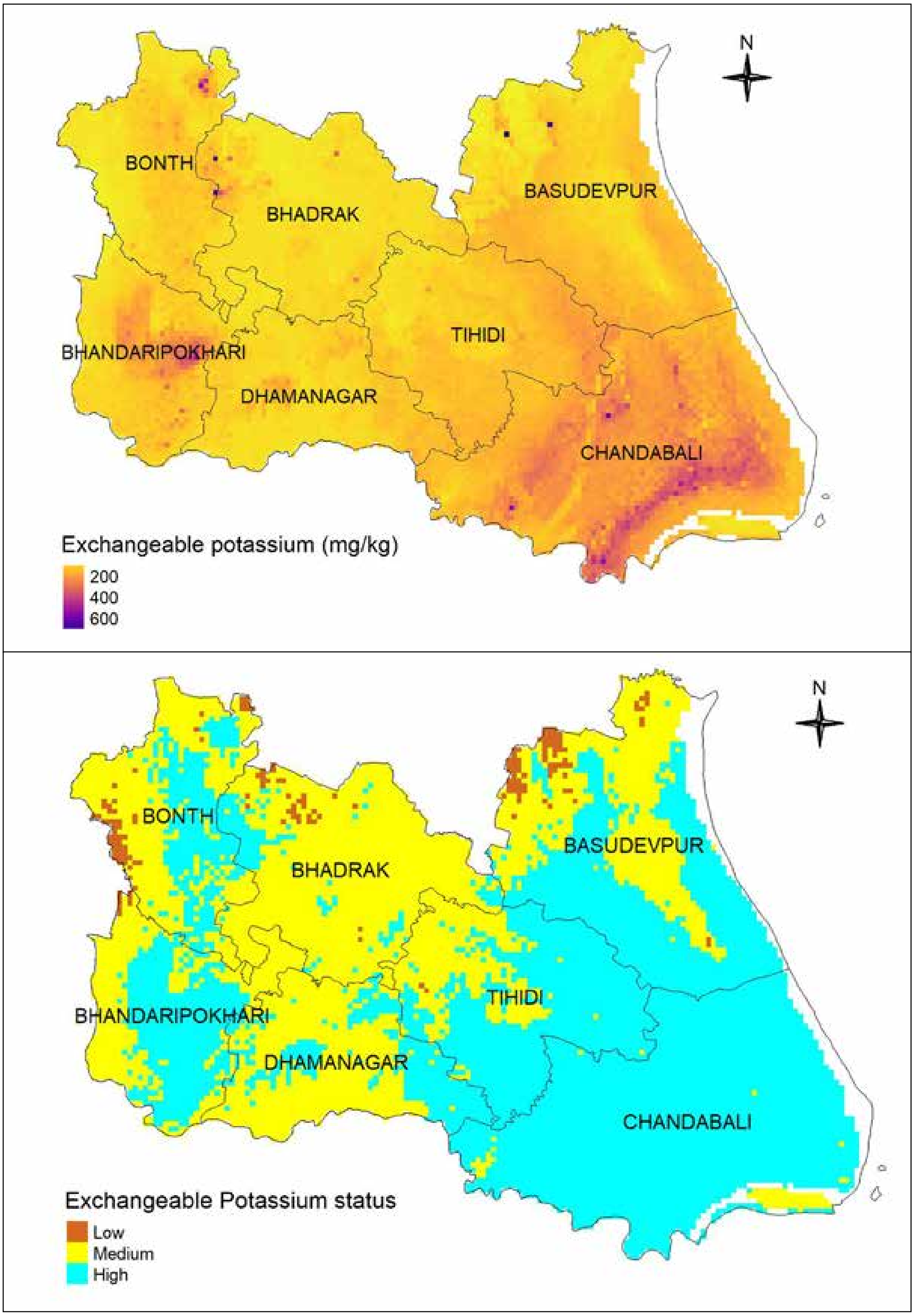


Figure 5.62. Status of exchangeable potassium in soils of Bhadrak district.

Available sulfur

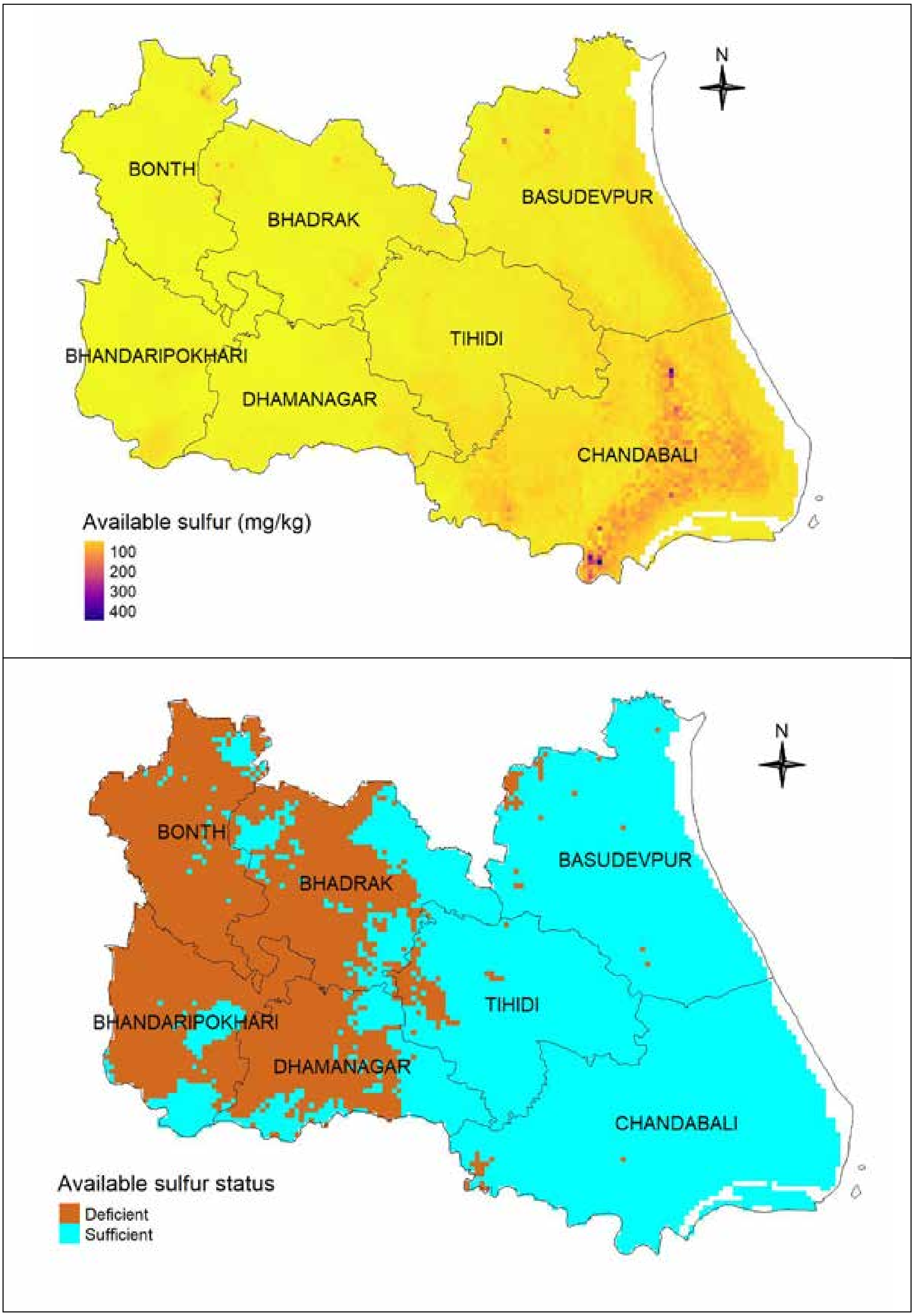


Figure 5.63. Status of available sulfur in soils of Bhadrak district.

Available Boron

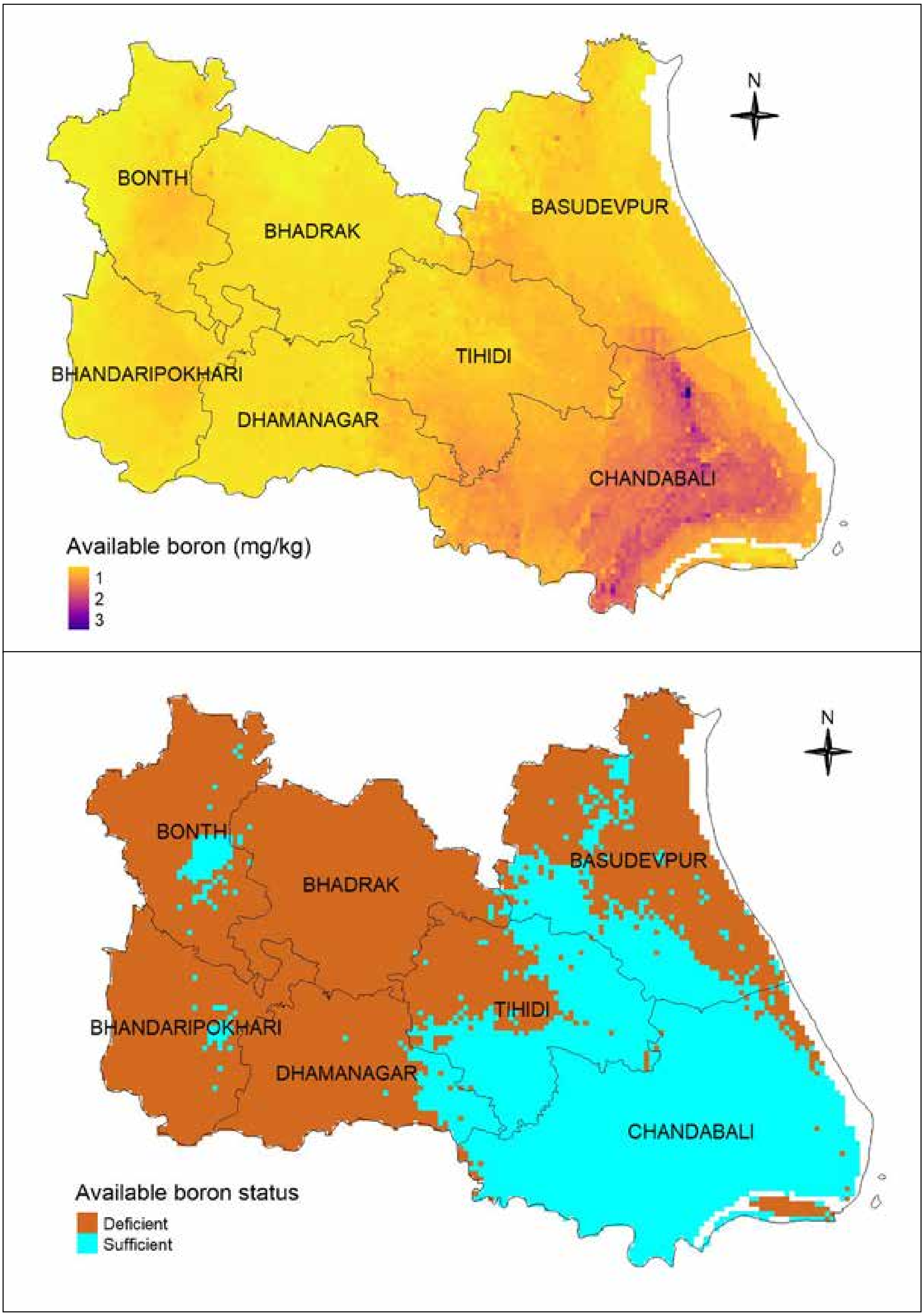


Figure 5.64. Status of available boron in soils of Bhadrak district.

Available Zinc

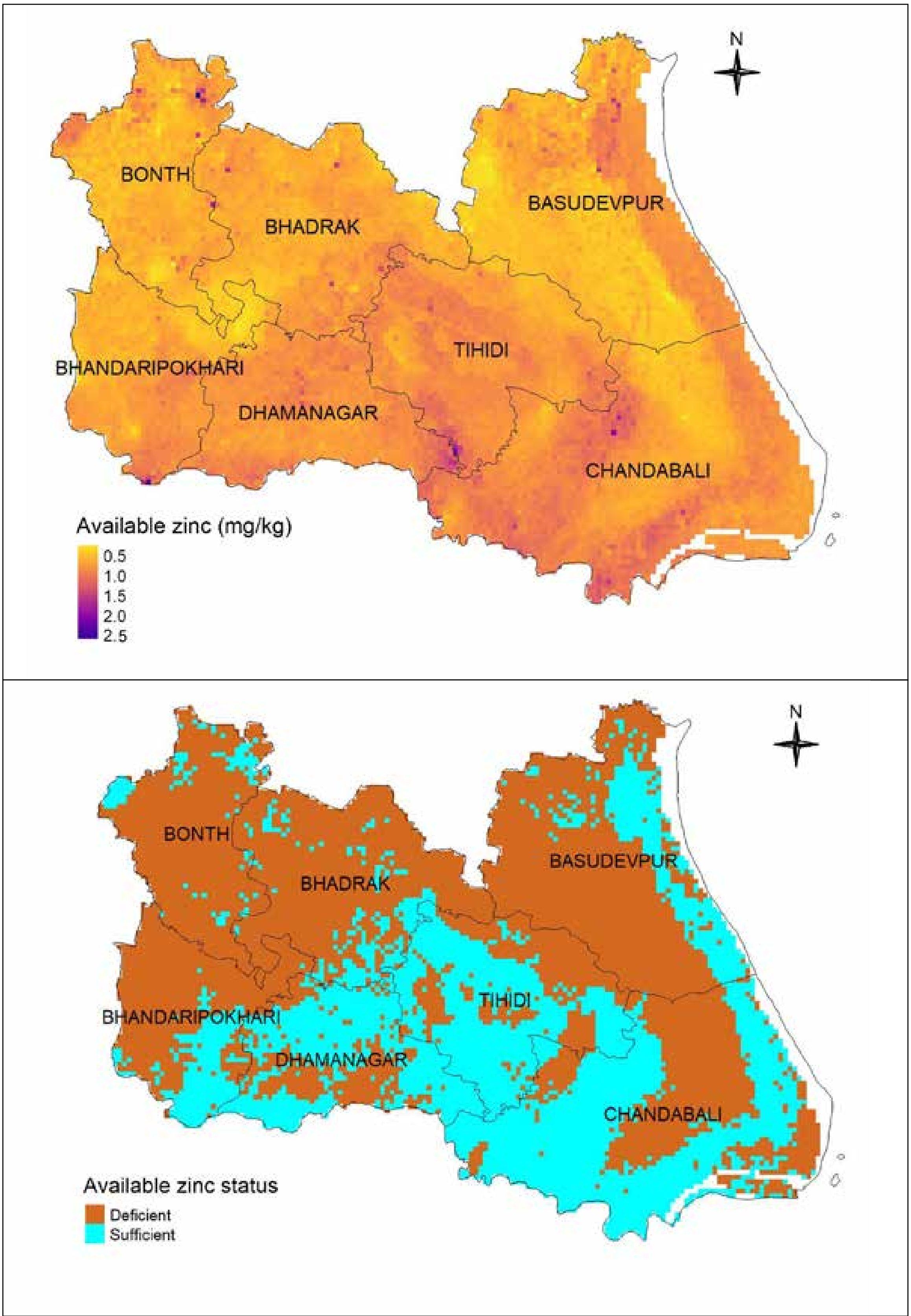


Figure 5.65. Status of available zinc in soils of Bhadrak district.

Boudh | pH

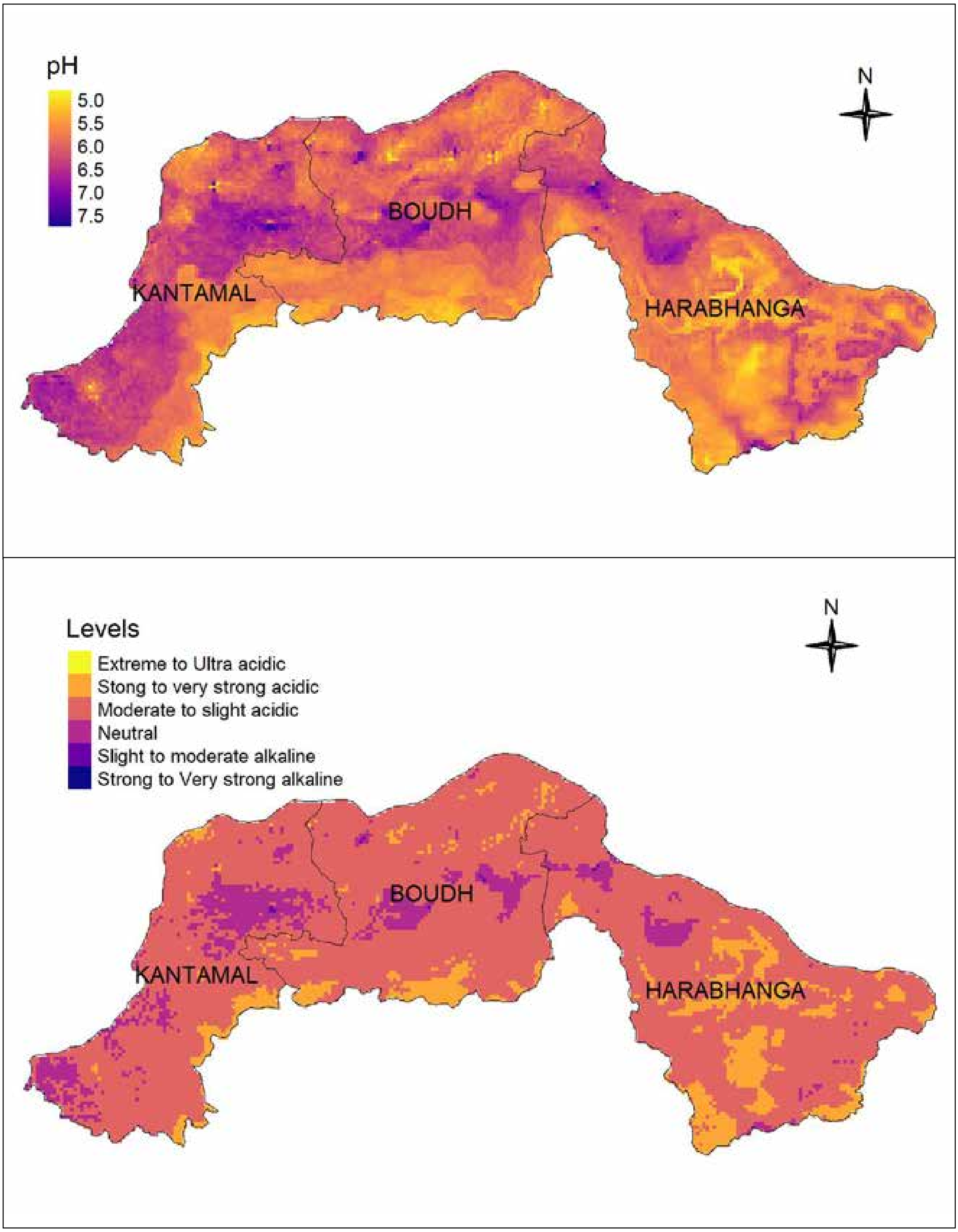


Figure 5.66. pH status in soils of Boudh district.

Electrical conductivity

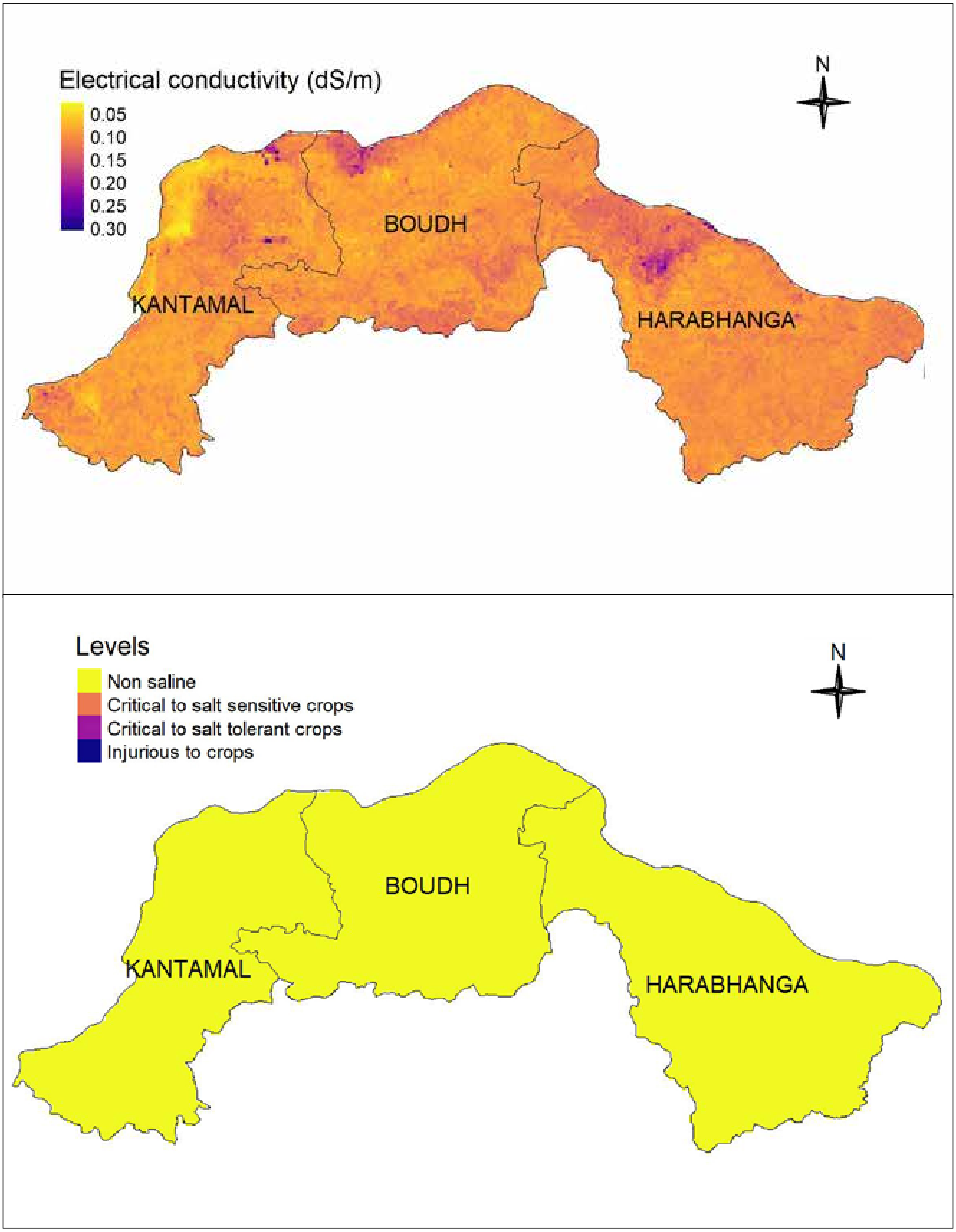


Figure 5.67. Status of electrical conductivity in soils of Boudh district.

Organic carbon

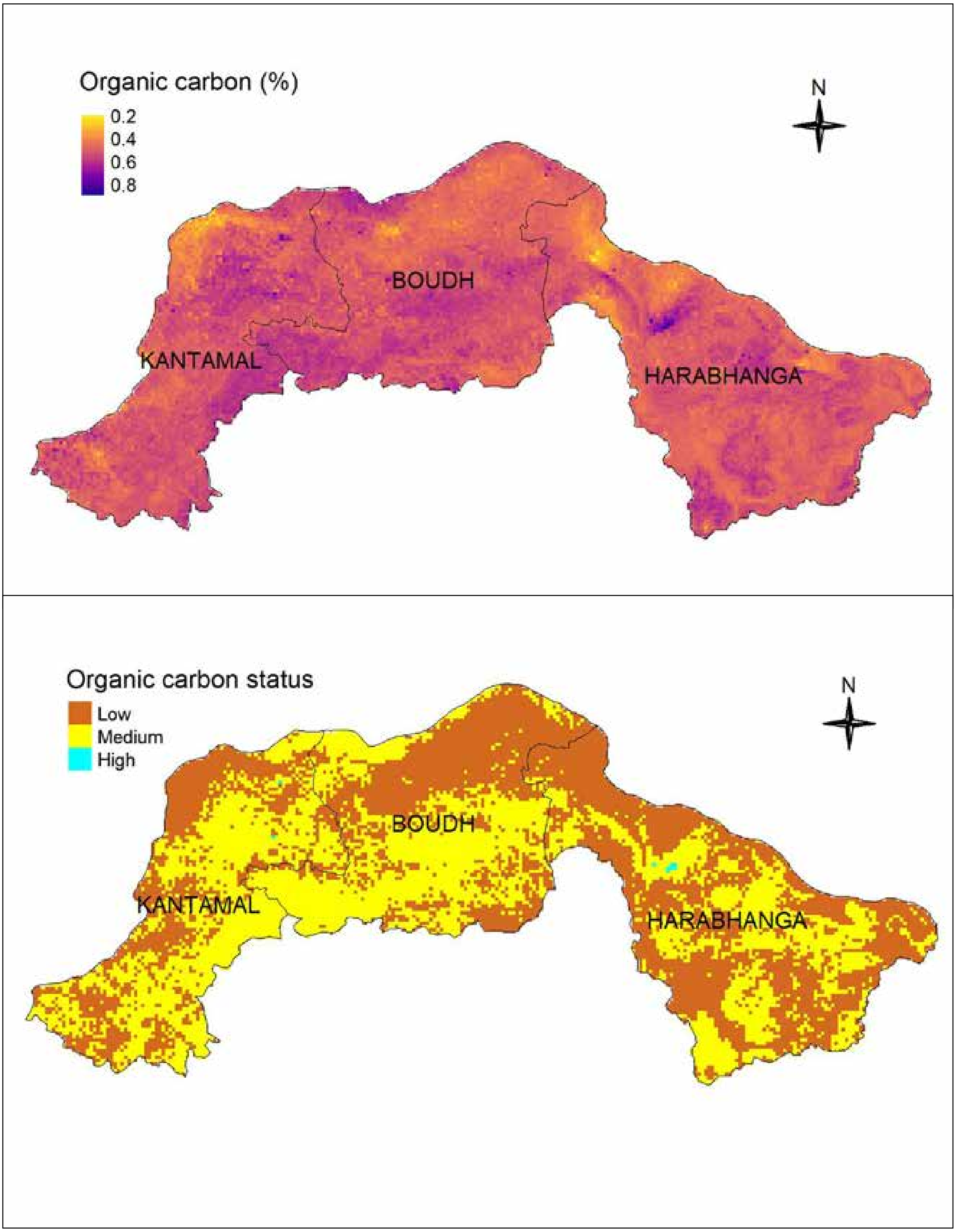


Figure 5.68. Organic carbon status in soils of Boudh district.

Available Phosphorous

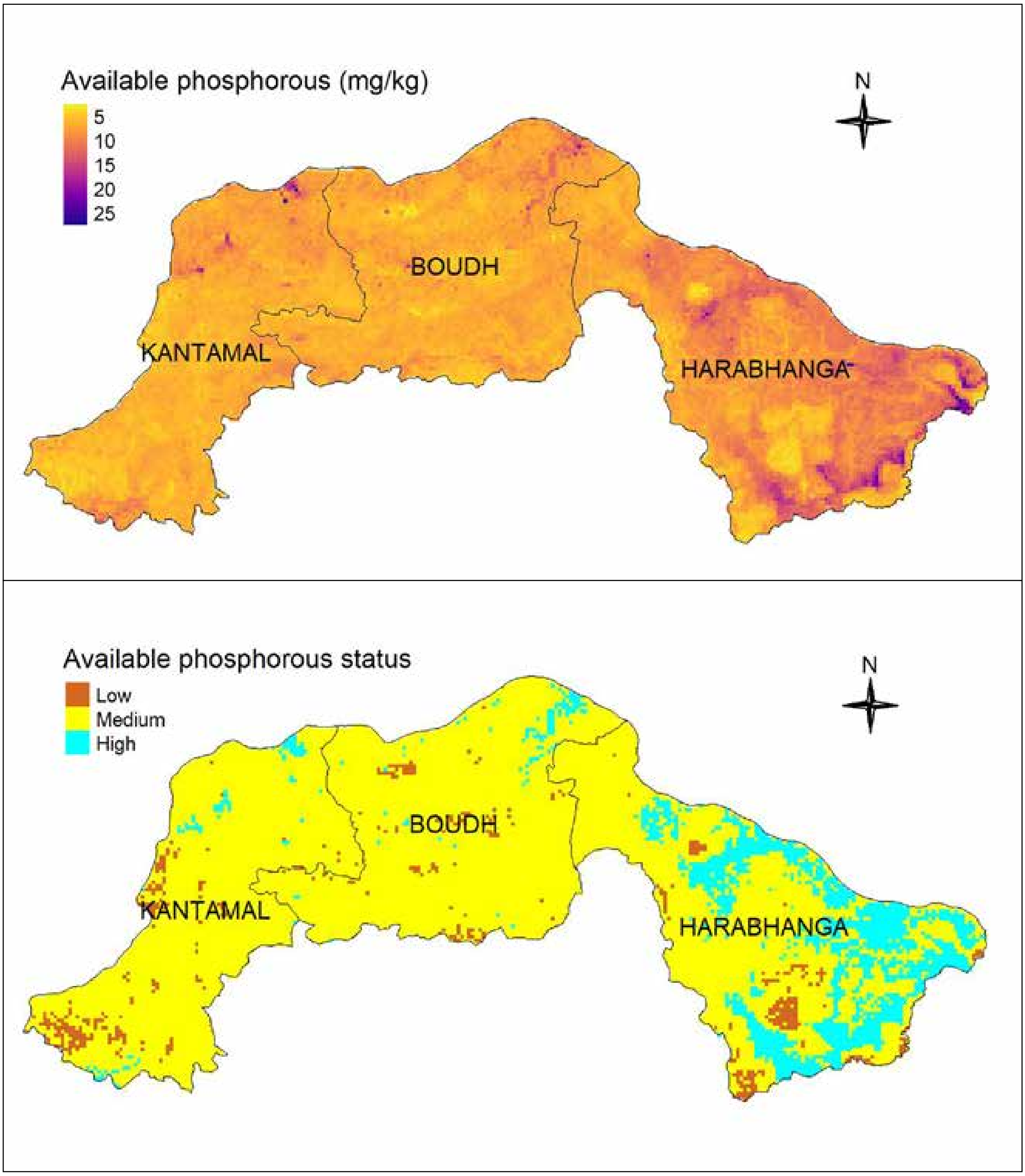


Figure 5.69. Status of available phosphorous in soils of Boudh district.

Exchangeable Potassium

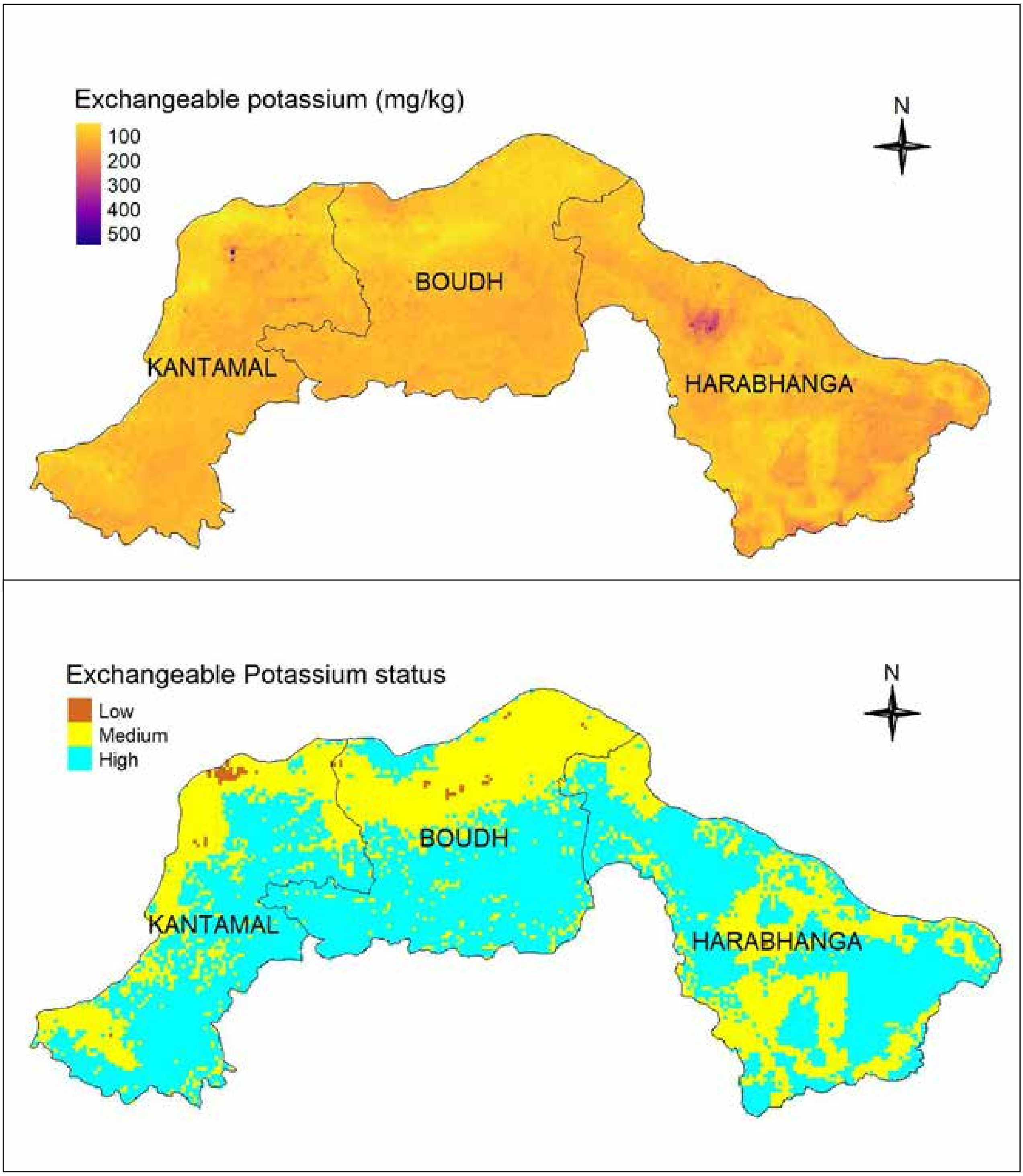


Figure 5.70. Status of exchangeable potassium in soils of Boudh district.

Available Sulfur

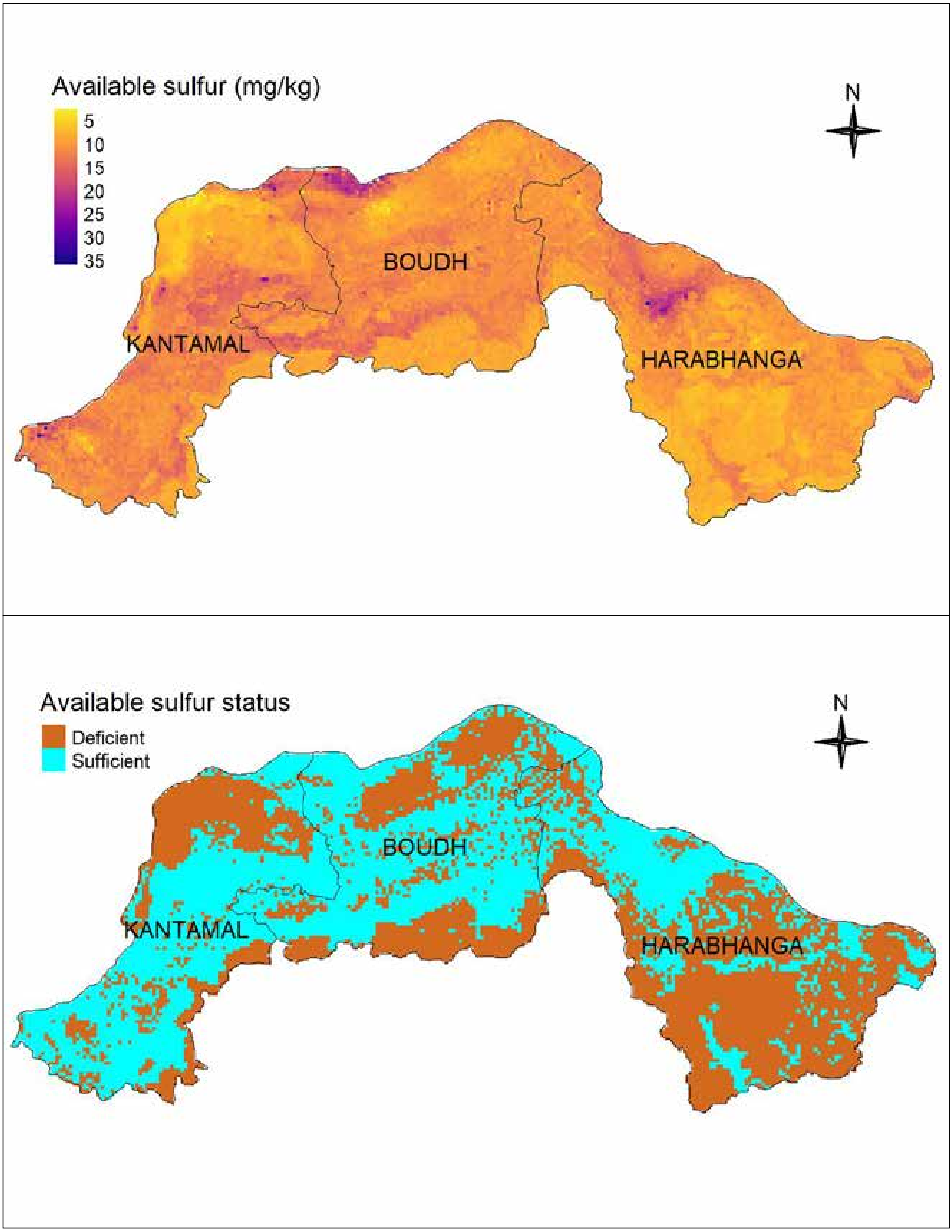


Figure 5.71. Status of available sulfur in soils of Boudh district.

Available Boron

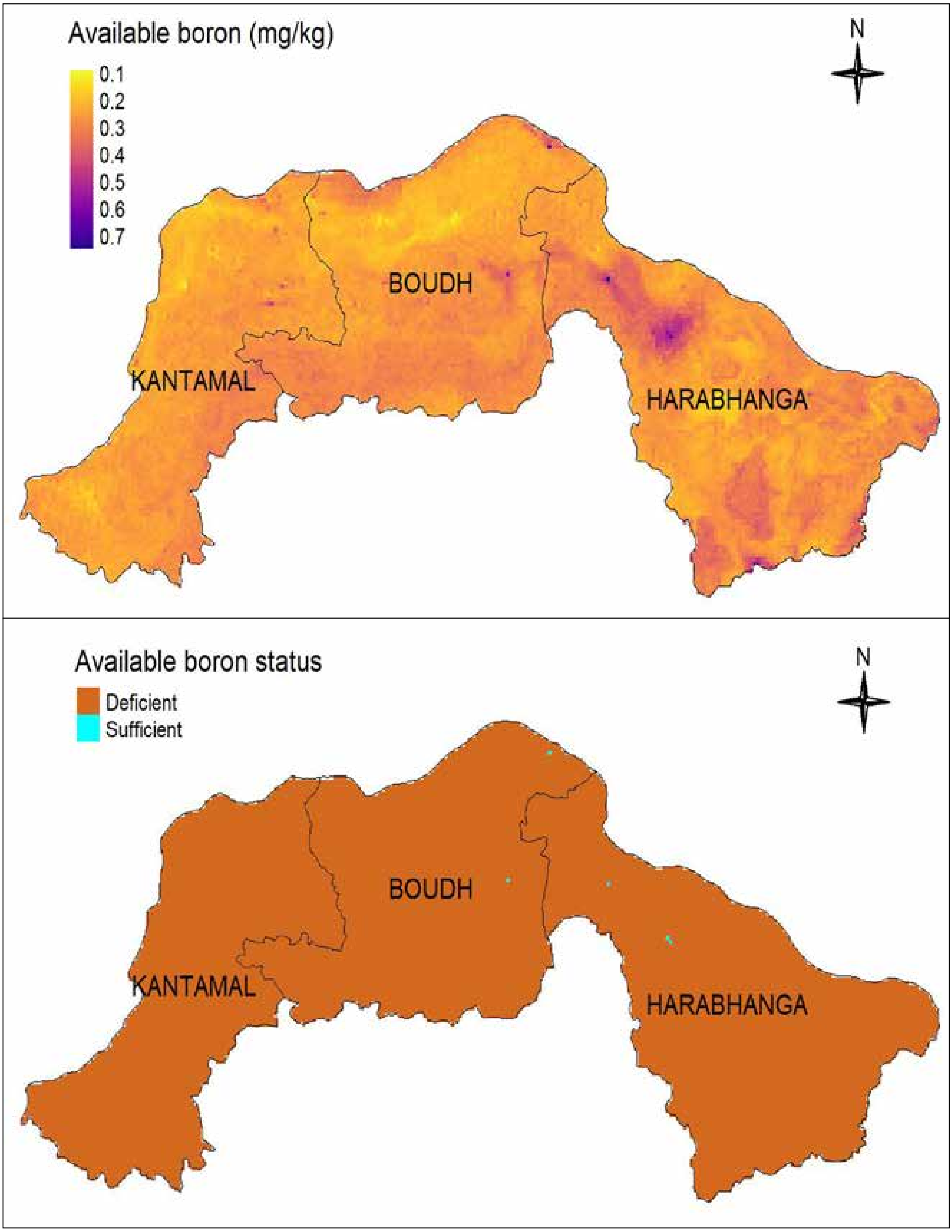


Figure 5.72. Status of available boron in soils of Boudh district.

Available Zinc

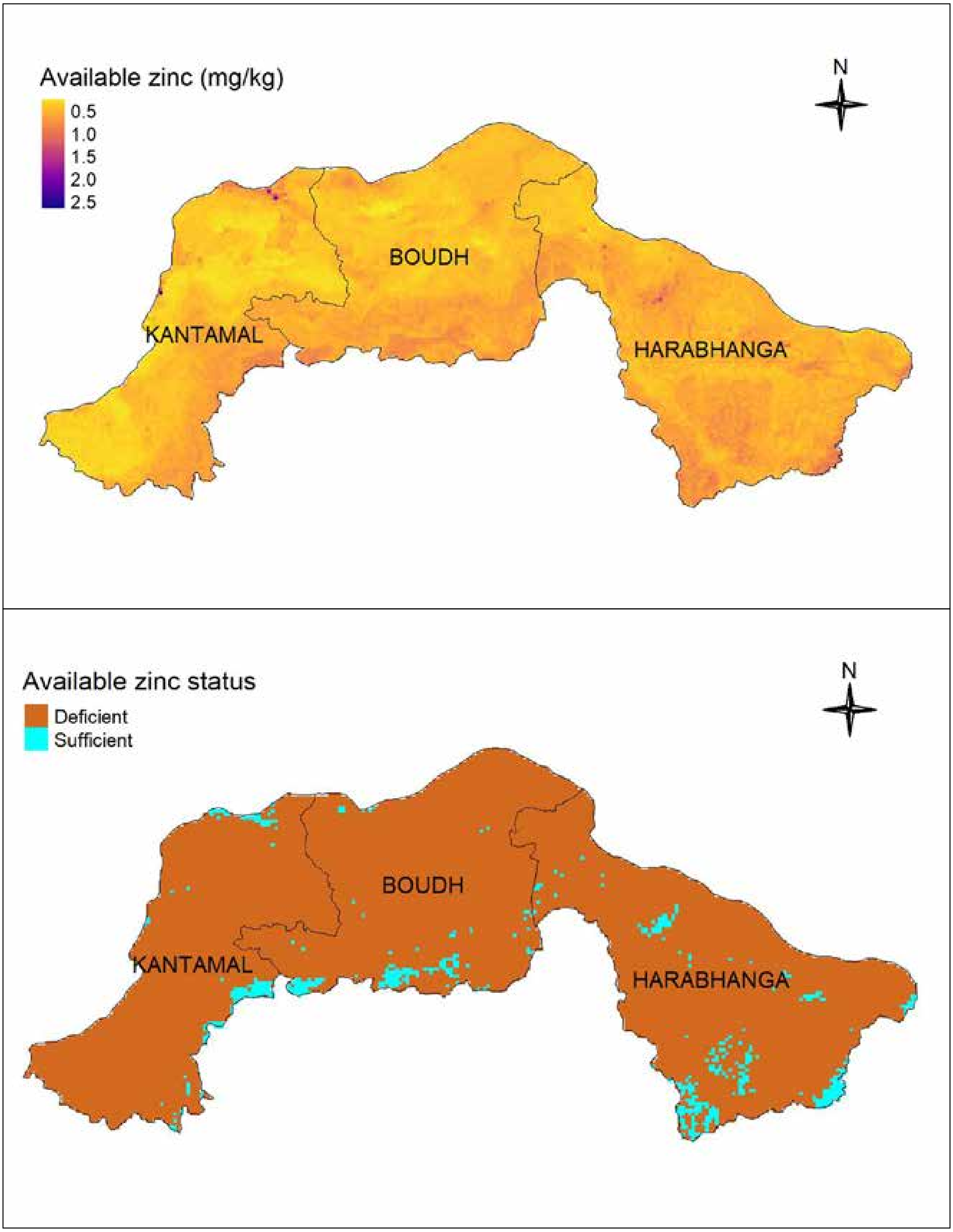
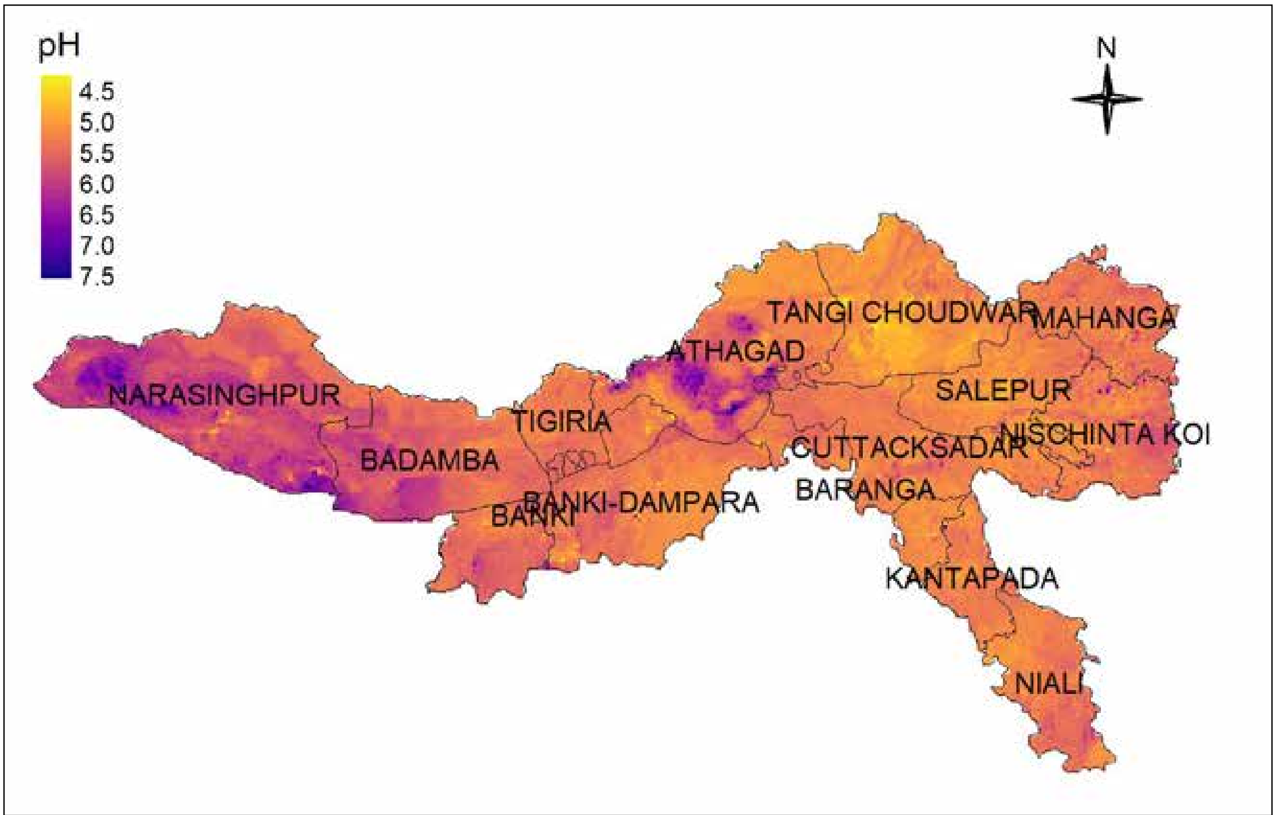


Figure 5.73. Status of available zinc in soils of Boudh district.

Cuttack | pH



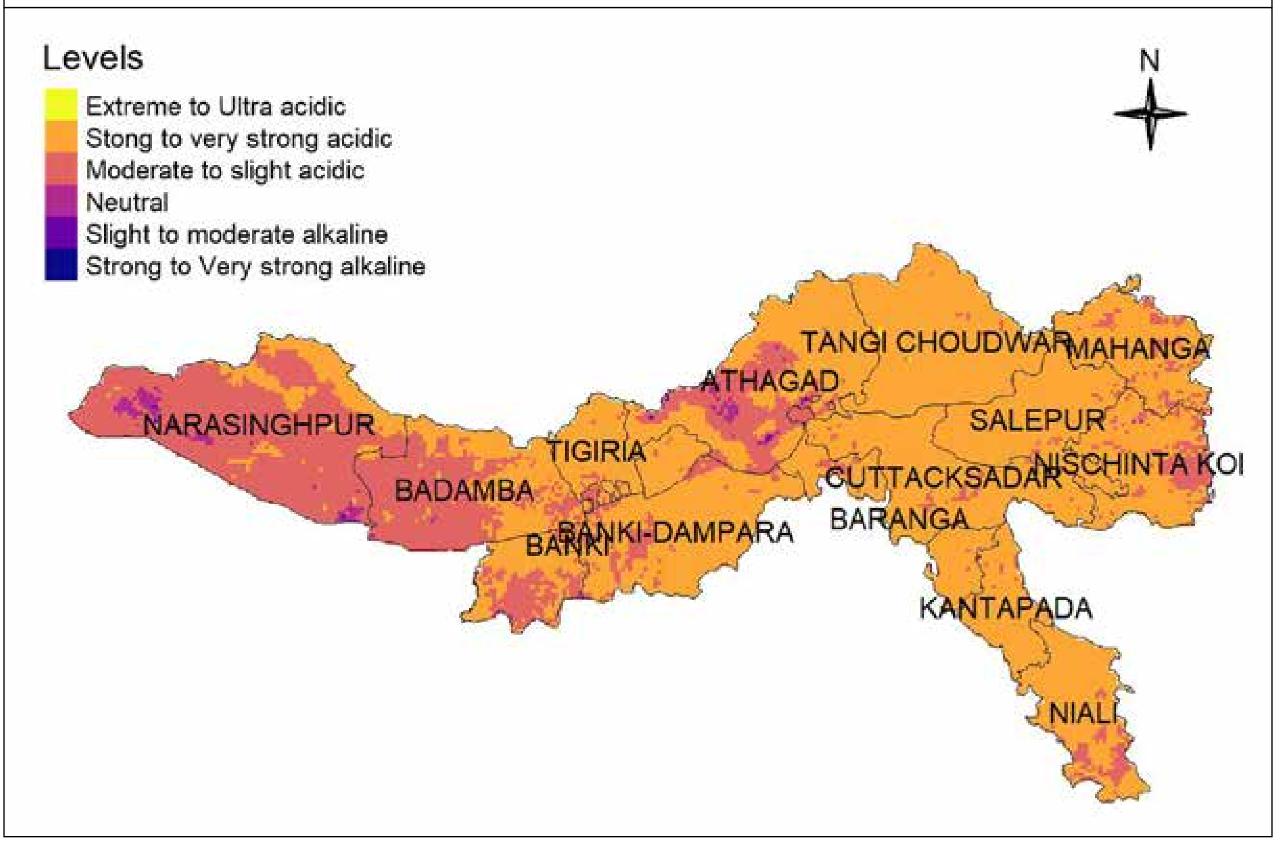


Figure 5.74. pH status in soils of Cuttack district.

Electrical conductivity

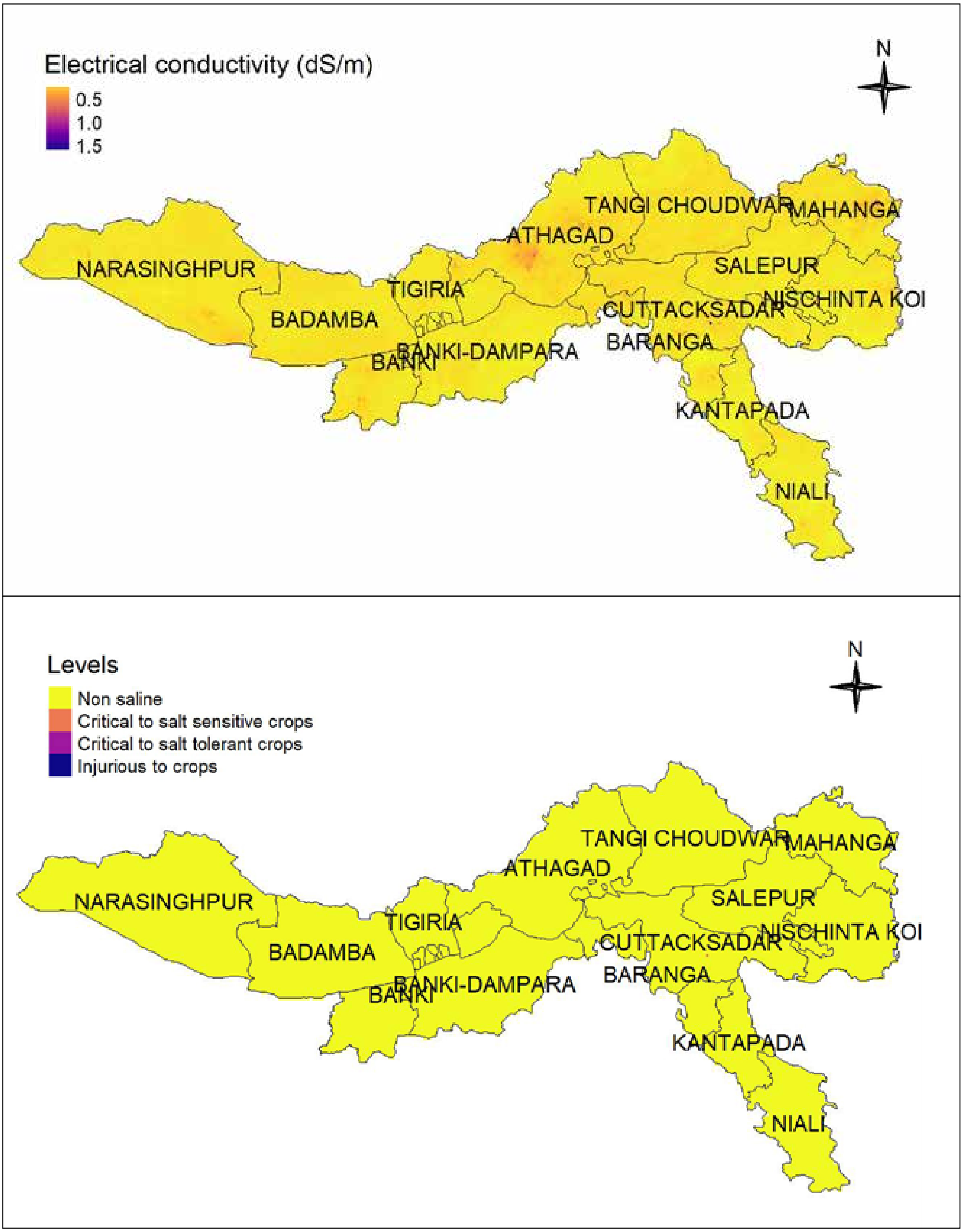


Figure 5.75. Status of electrical conductivity in soils of Cuttack district.

Organic carbon

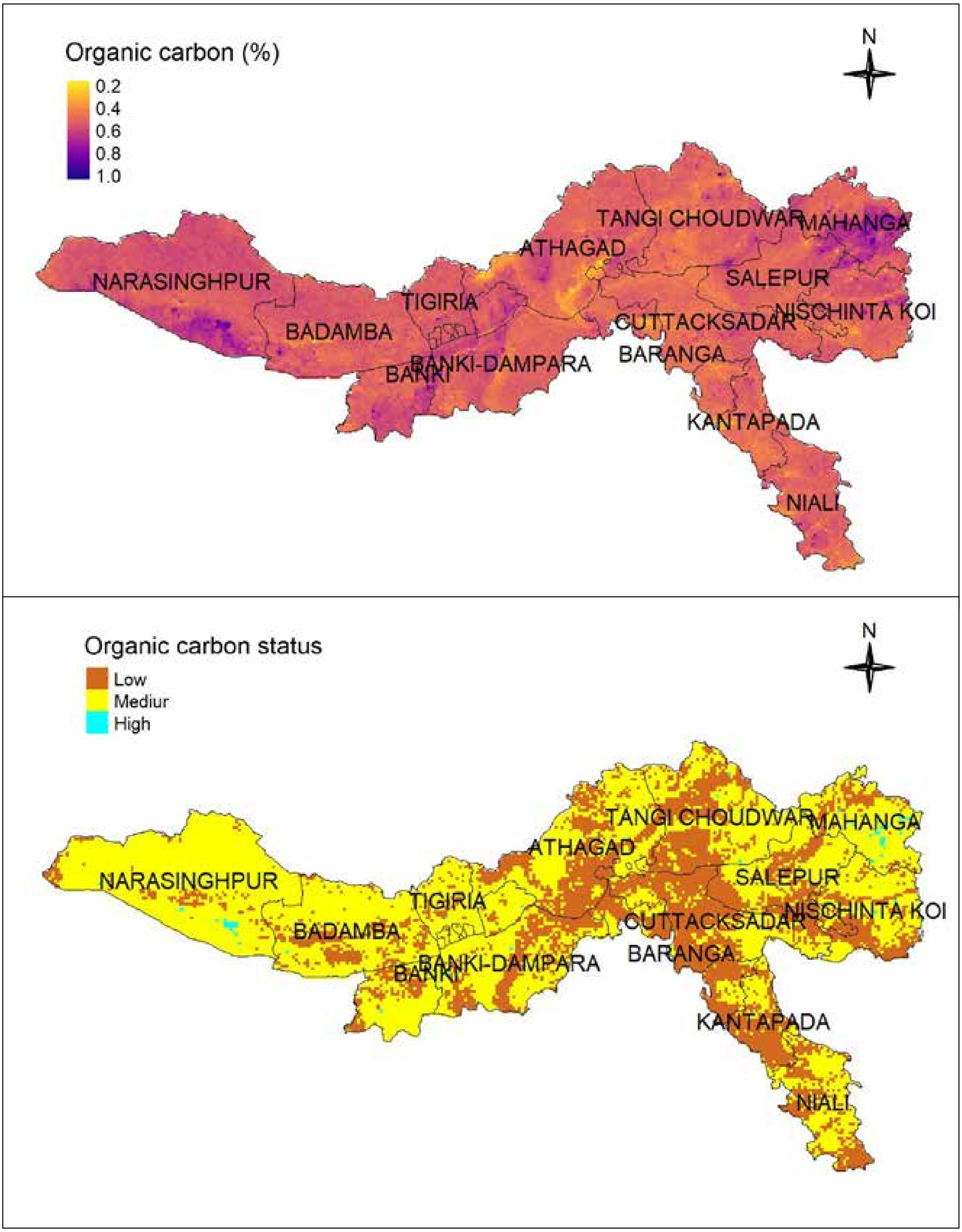


Figure 5.76. Organic carbon status in soils of Cuttack district.

Available Phosphorous

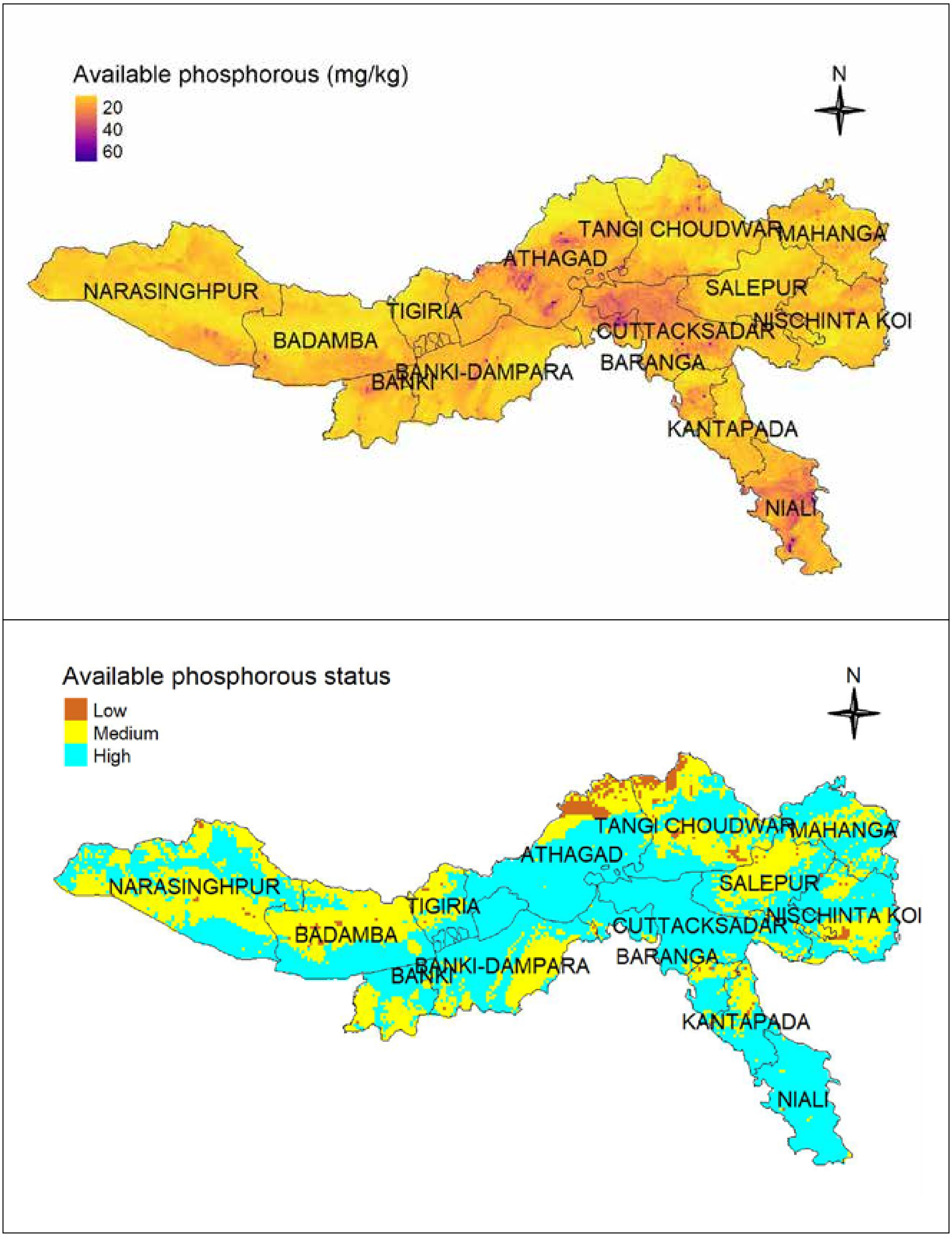


Figure 5.77. Status of available phosphorous in soils of Cuttack district.

Exchangeable Potassium

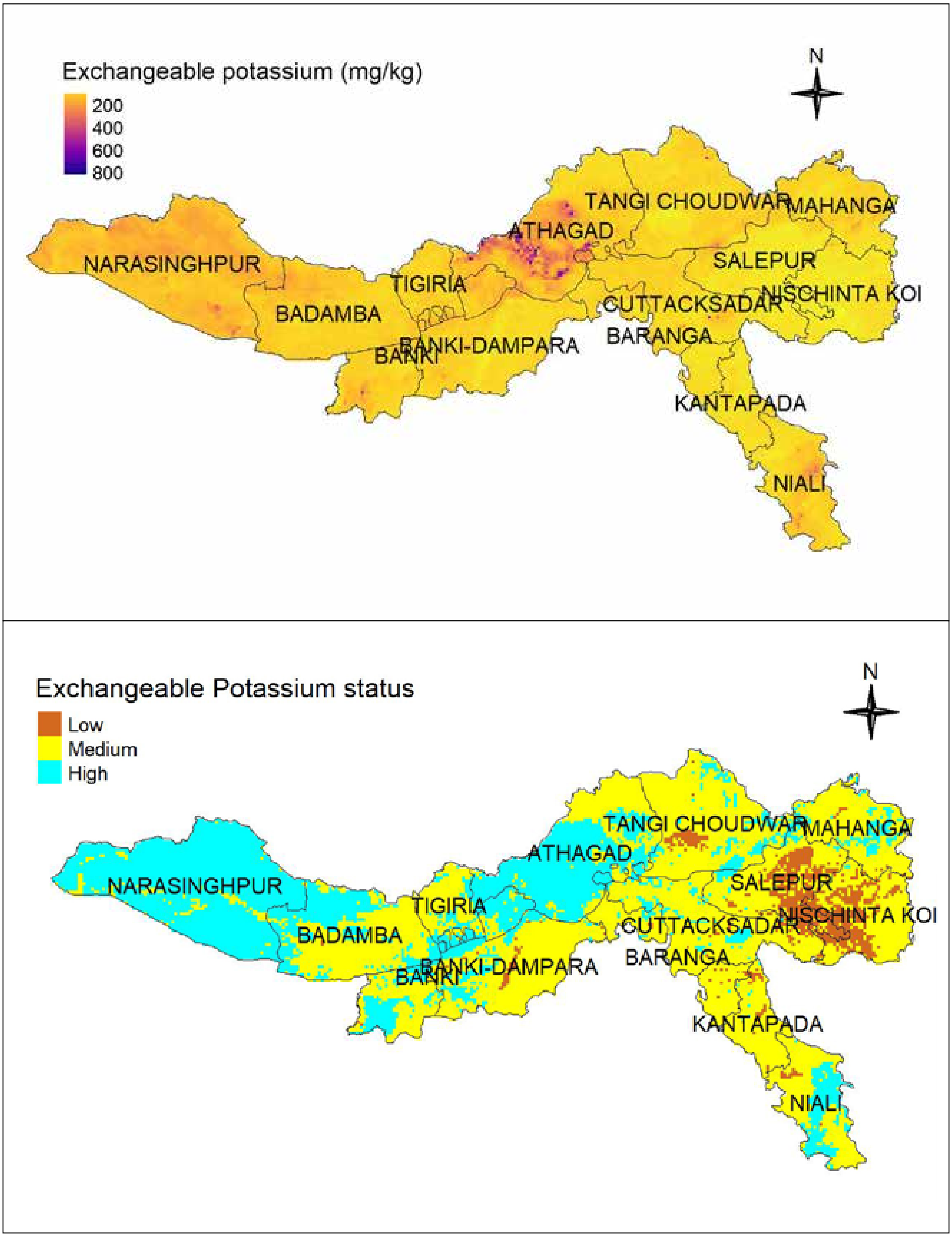


Figure 5.78. Status of exchangeable potassium in soils of Cuttack district.

Available Sulfur

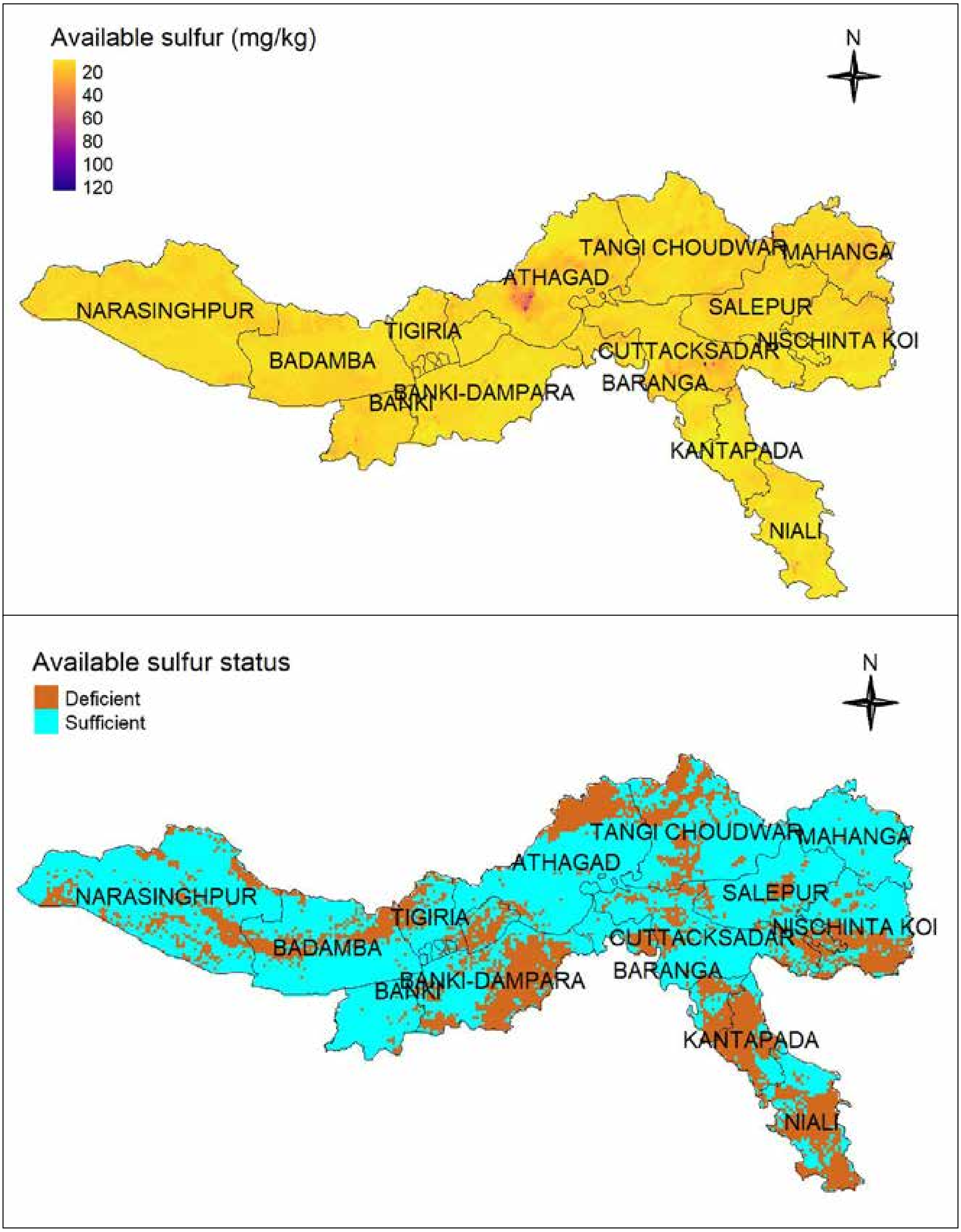


Figure 5.79. Status of available sulfur in soils of Cuttack district.

Available Boron

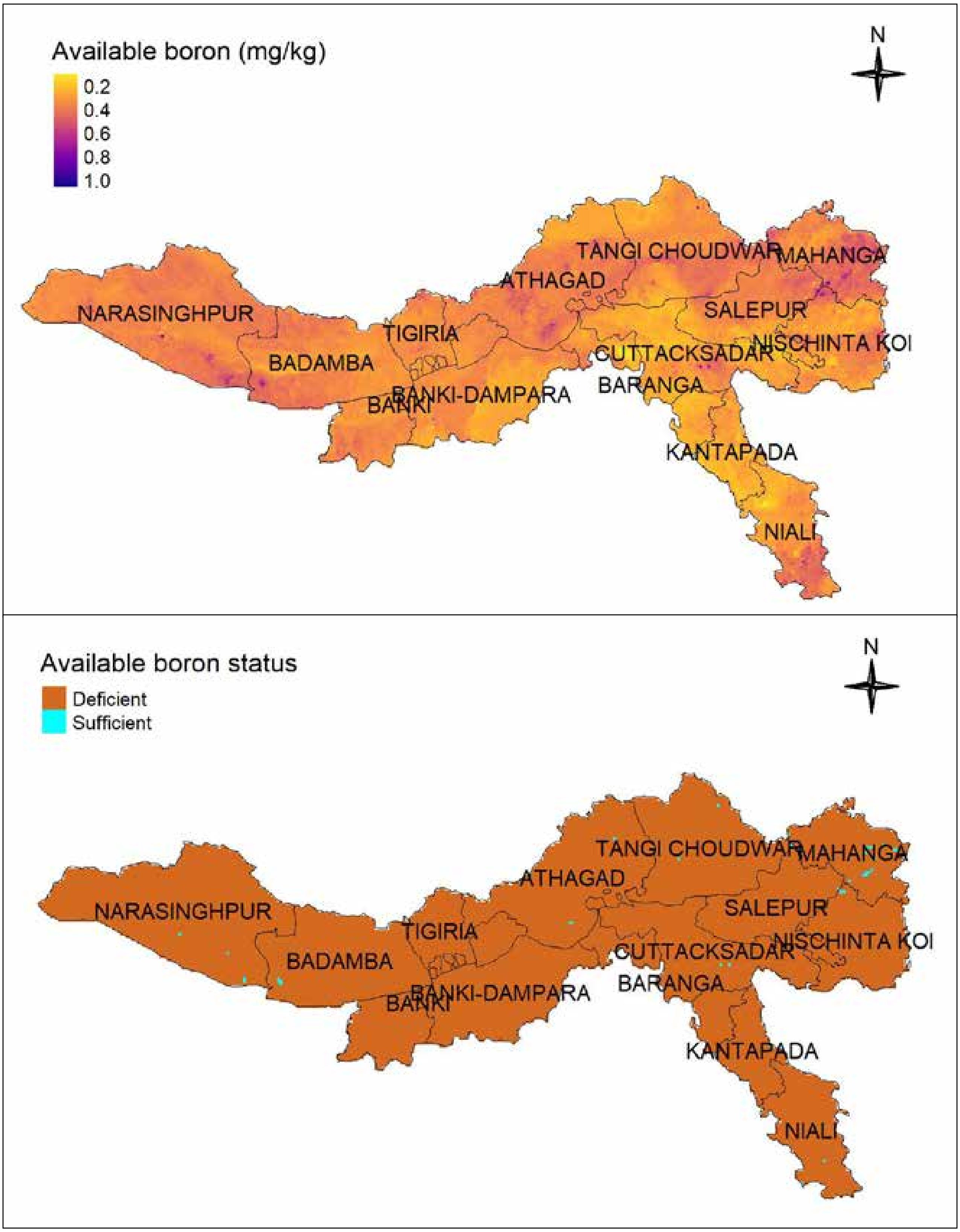


Figure 5.80. Status of available boron in soils of Cuttack district.

Available Zinc

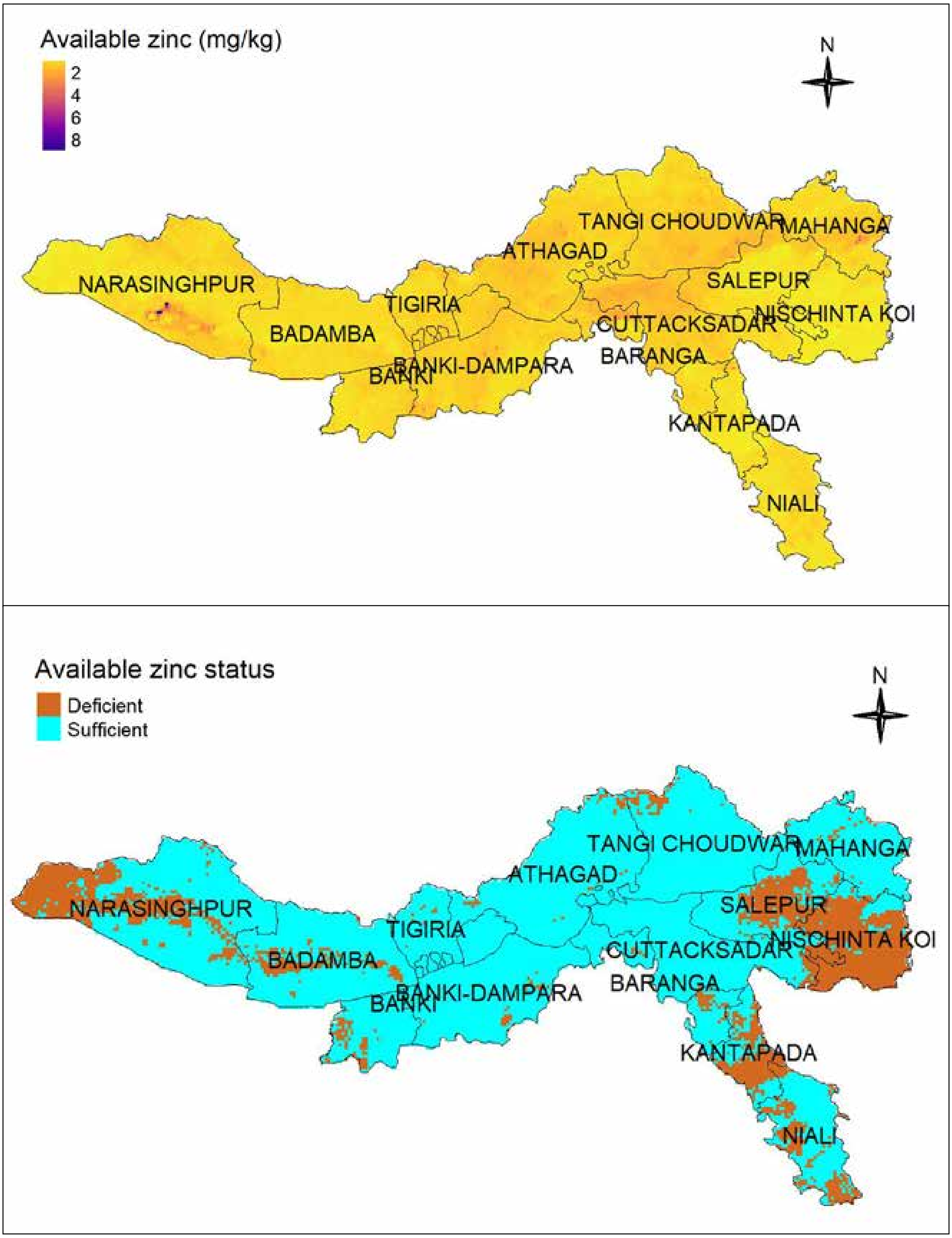


Figure 5.81. Status of available zinc in soils of Cuttack district.

Deogarh | pH

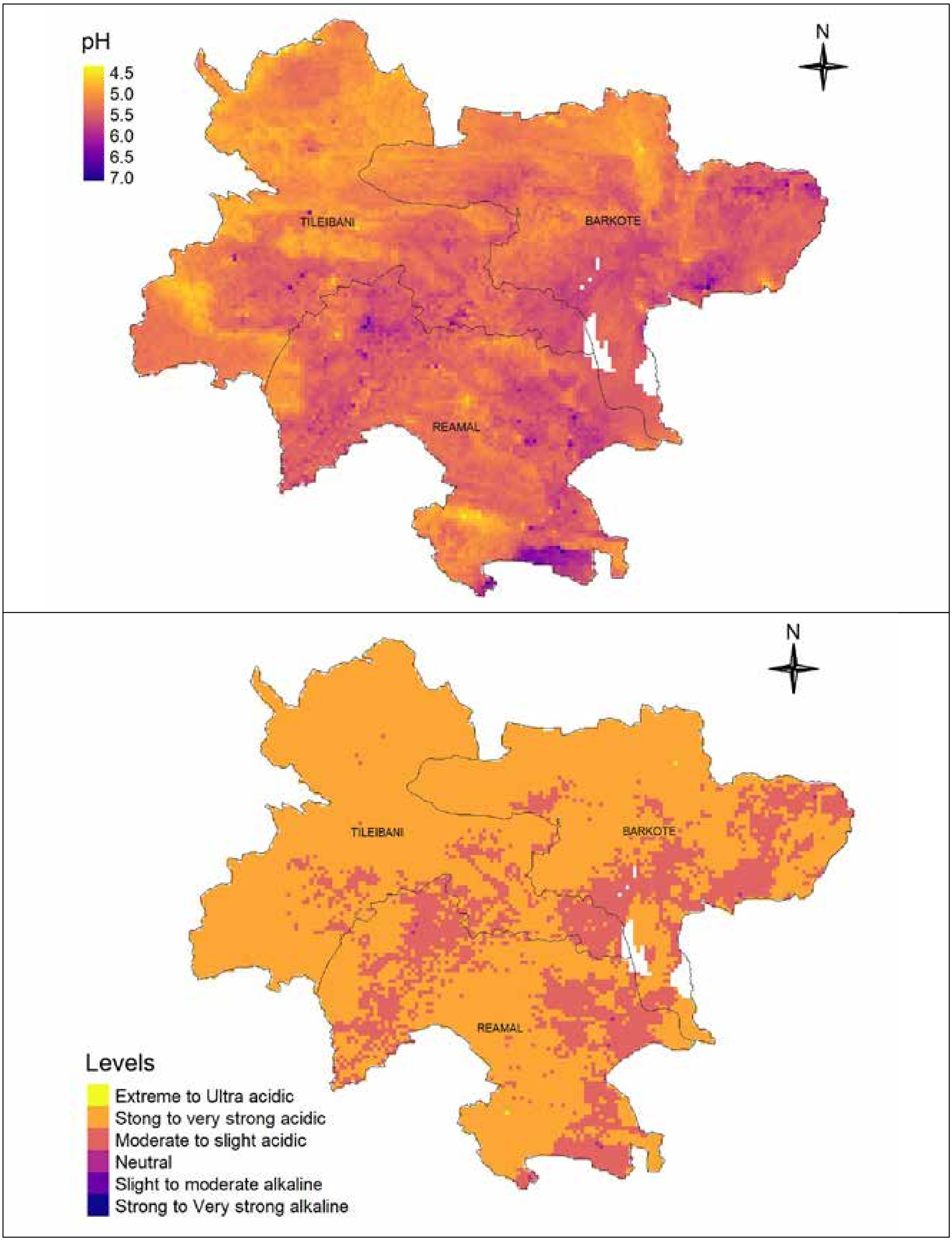


Figure 5.82. pH status in soils of Deogarh district.

Electrical conductivity

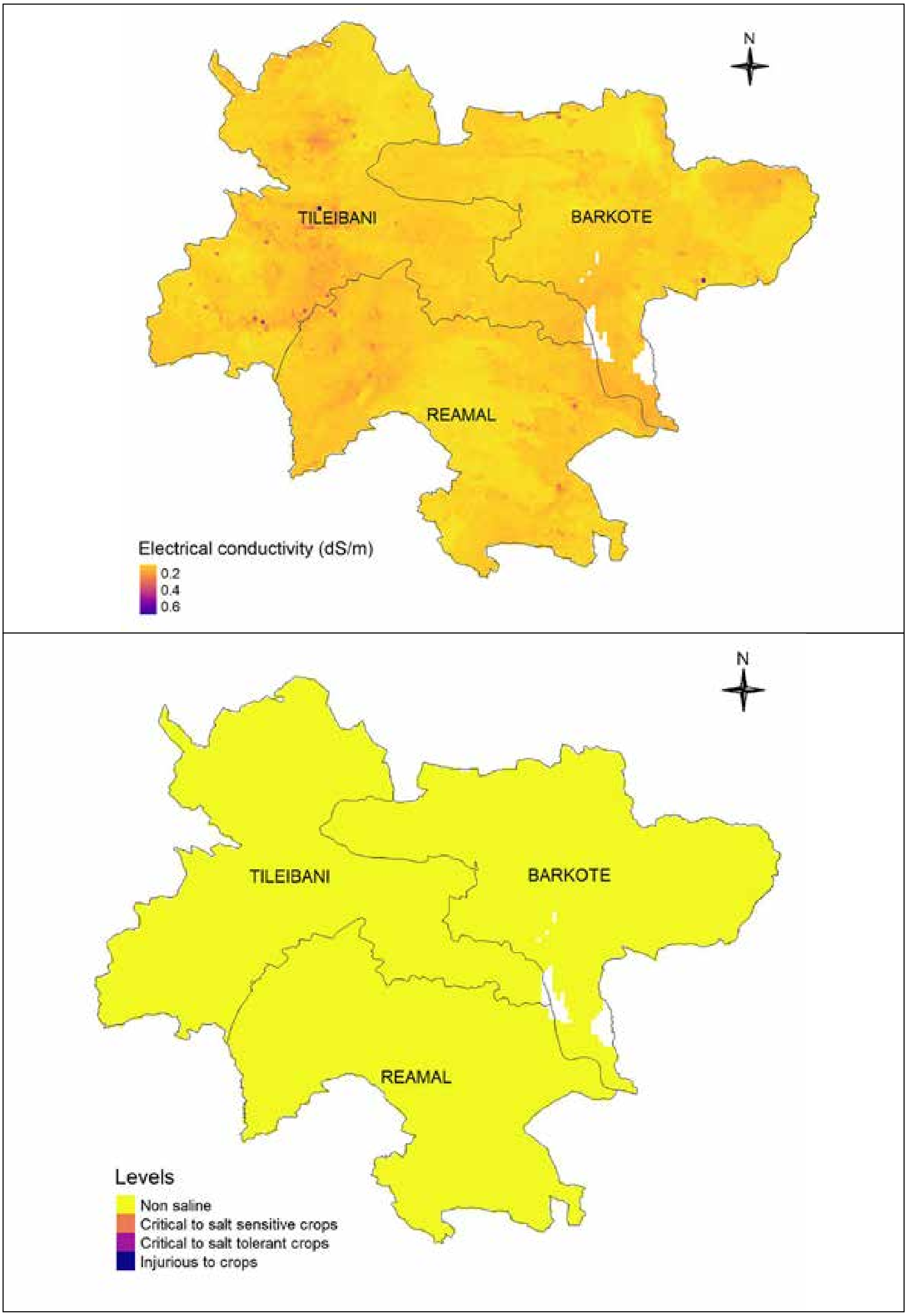


Figure 5.83. Status of electrical conductivity in soils of Deogarh district.

Organic carbon

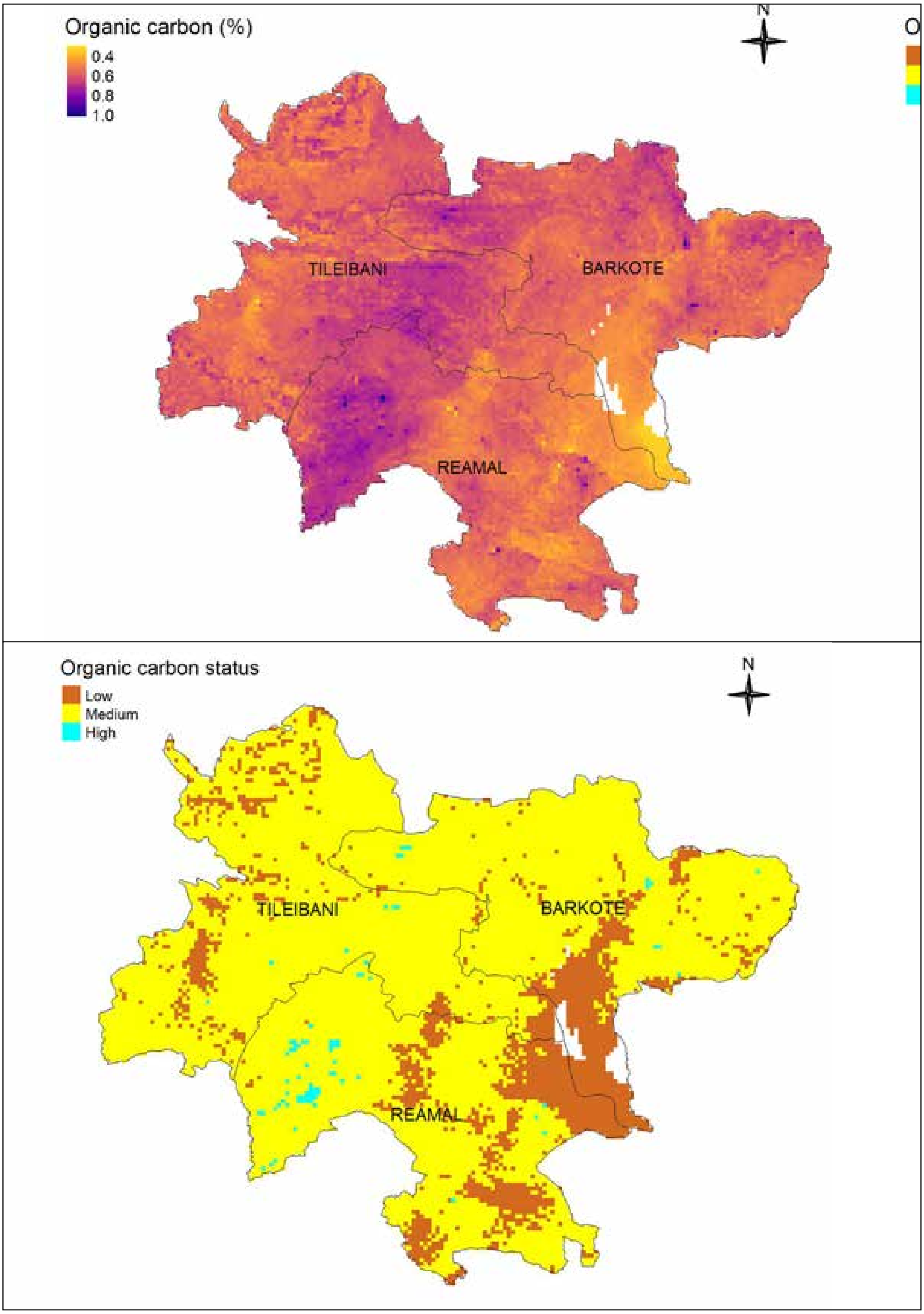


Figure 5.84. Organic carbon status in soils of Deogarh district.

Available Phosphorous

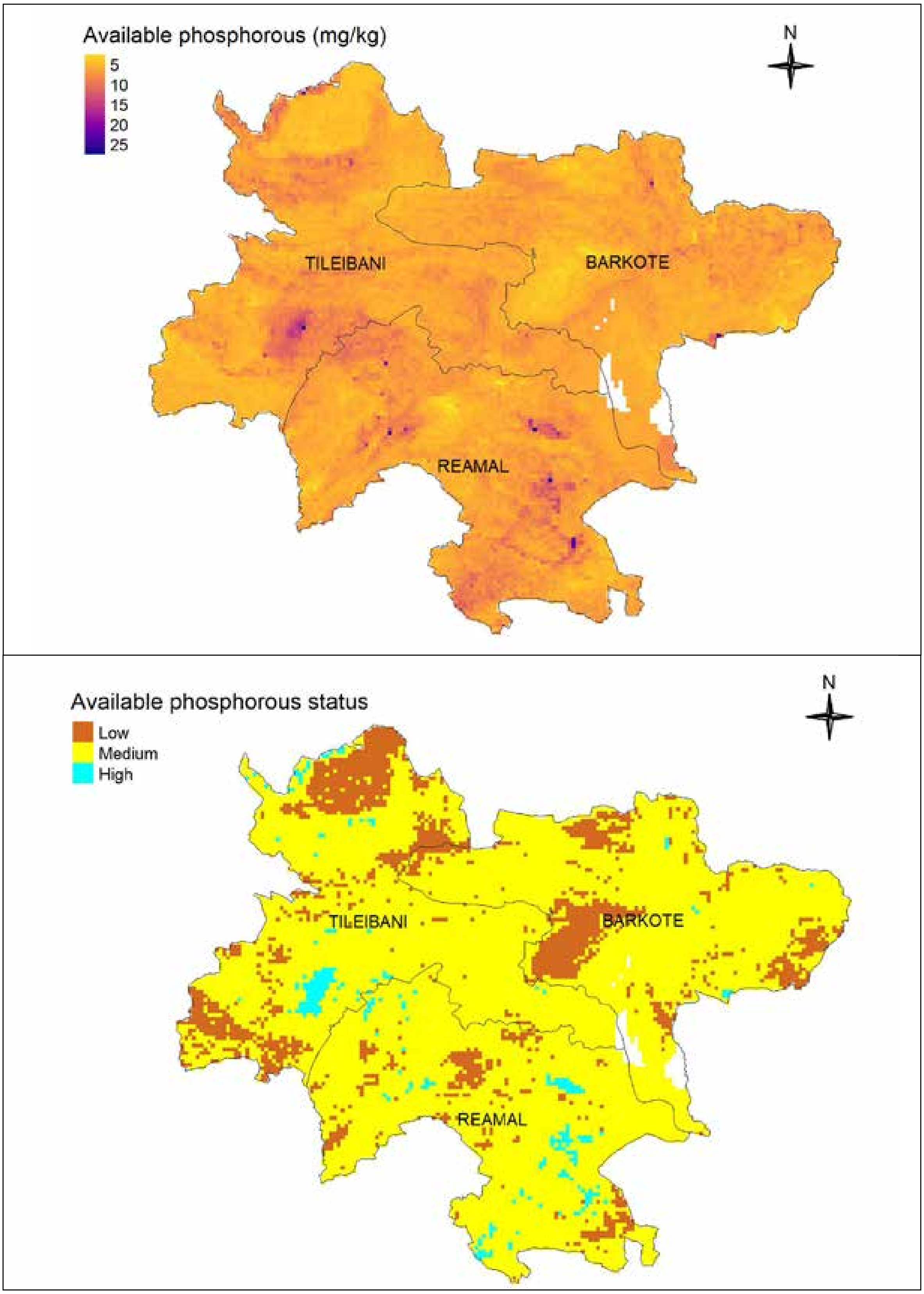


Figure 5.85. Status of available phosphorous in soils of Deogarh district.

Exchangeable Potassium

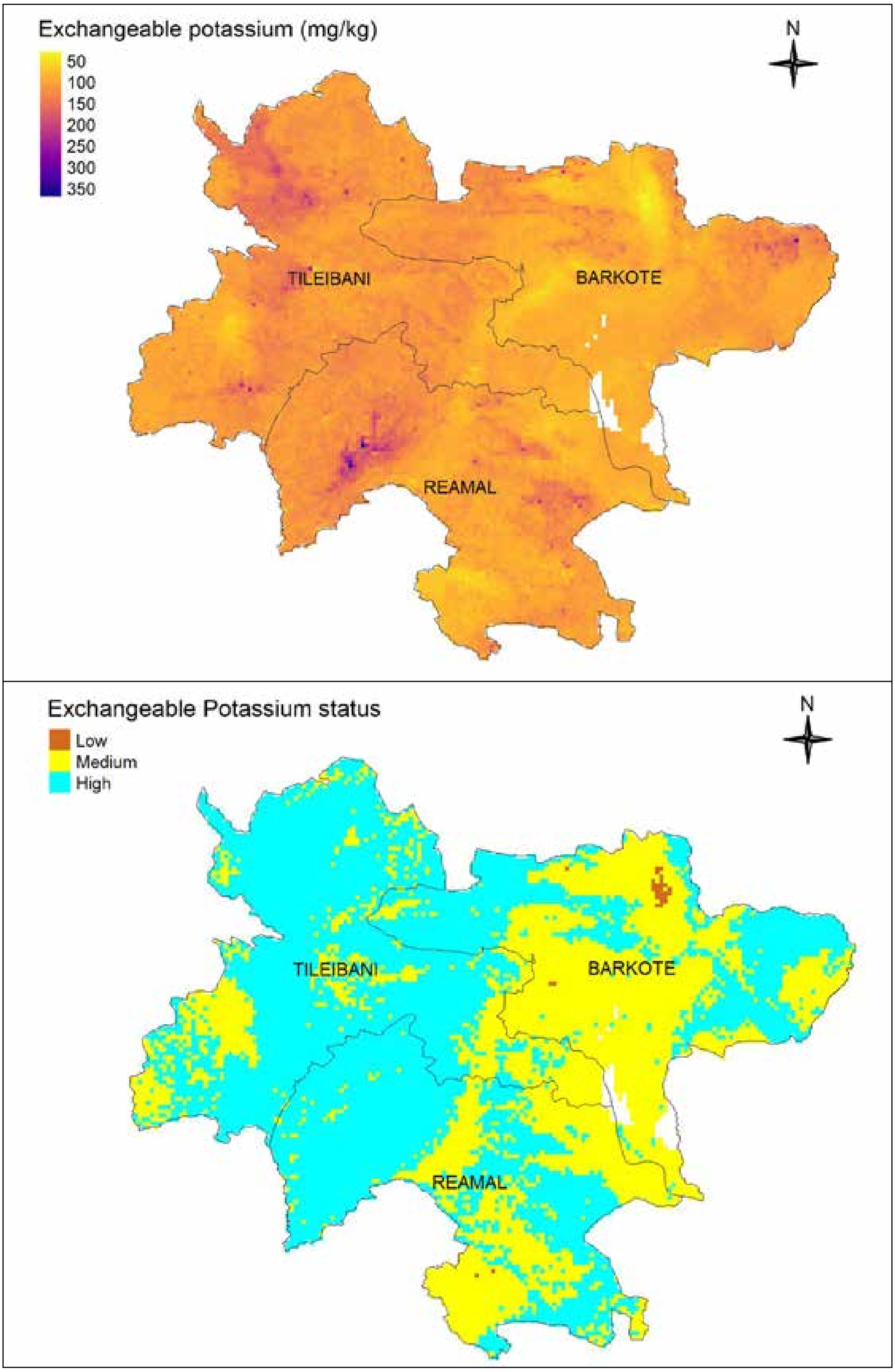


Figure 5.86. Status of exchangeable potassium in soils of Deogarh district.

Available Sulfur

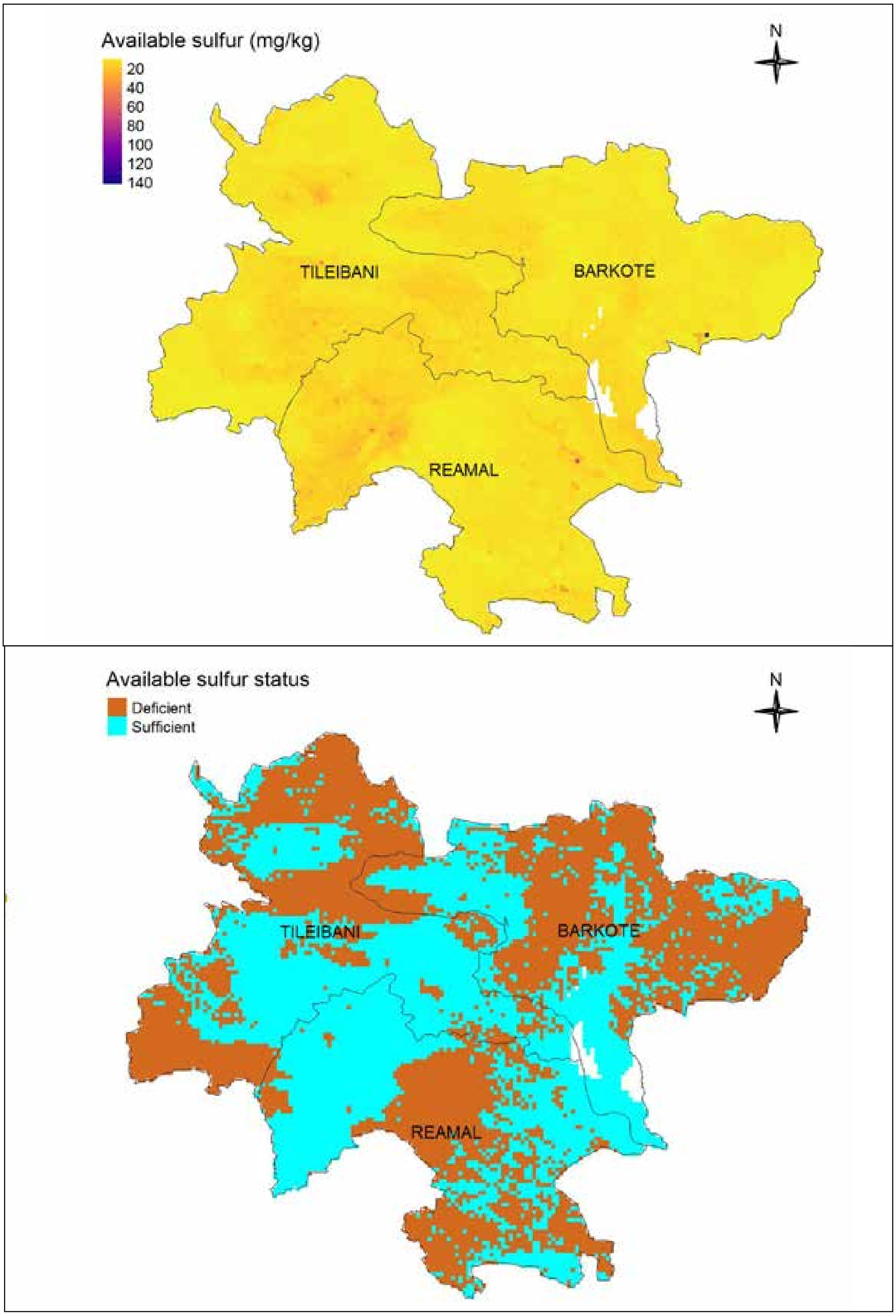


Figure 5.87. Status of available sulfur in soils of Deogarh district.

Available Boron

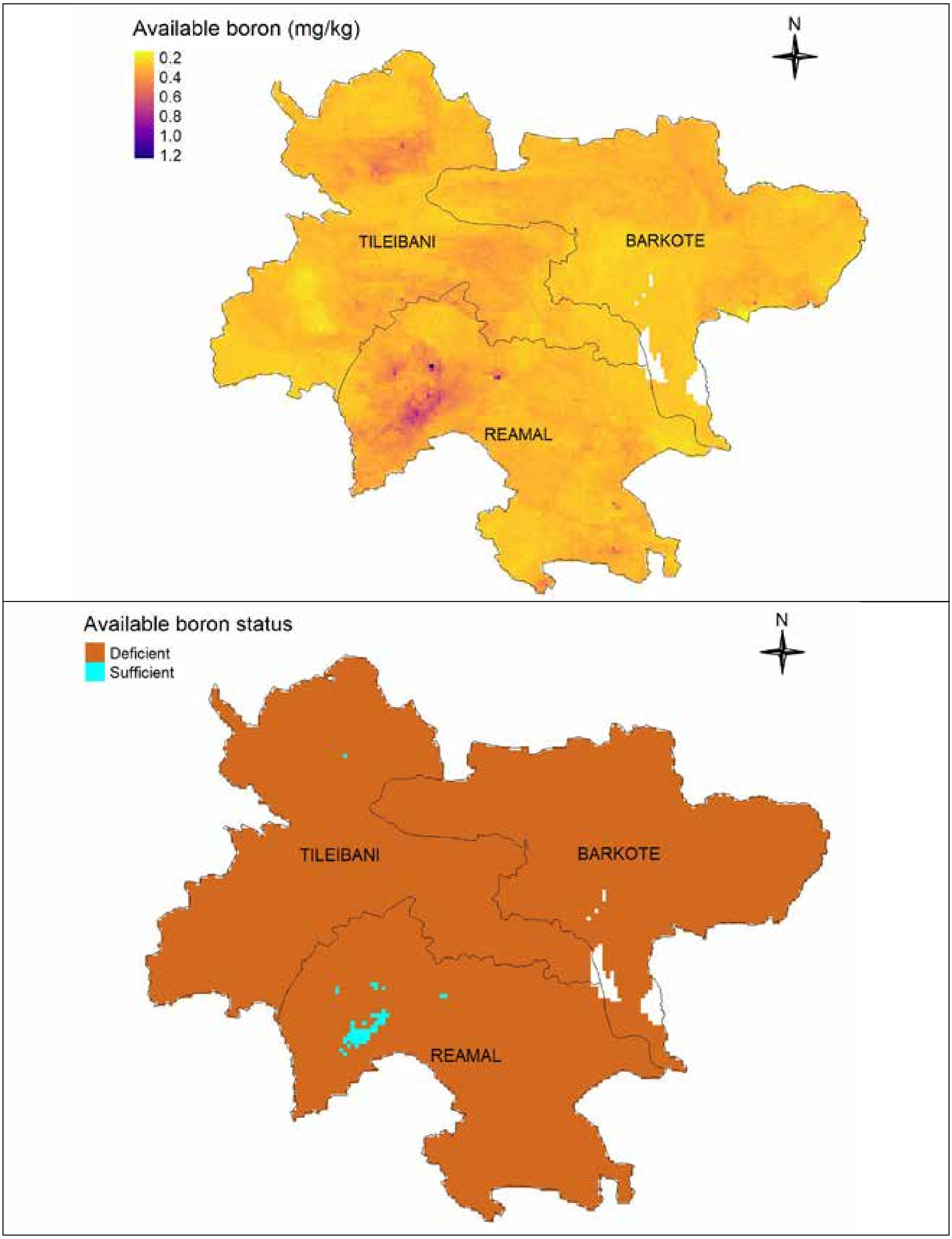


Figure 5.88. Status of available boron in soils of Deogarh district.

Available Zinc

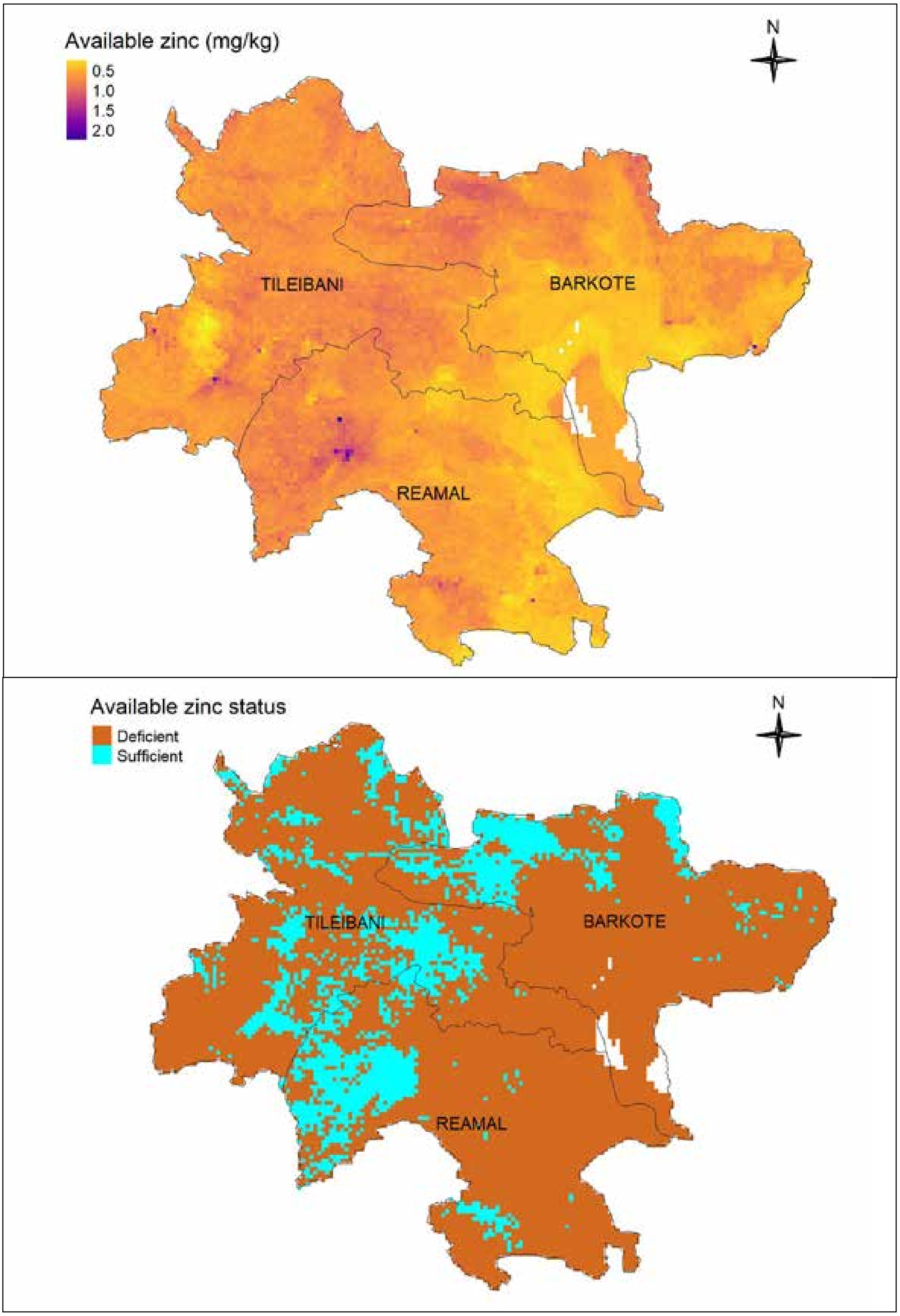


Figure 5.89. Status of available zinc in soils of Deogarh district.

Dhenkanal | pH

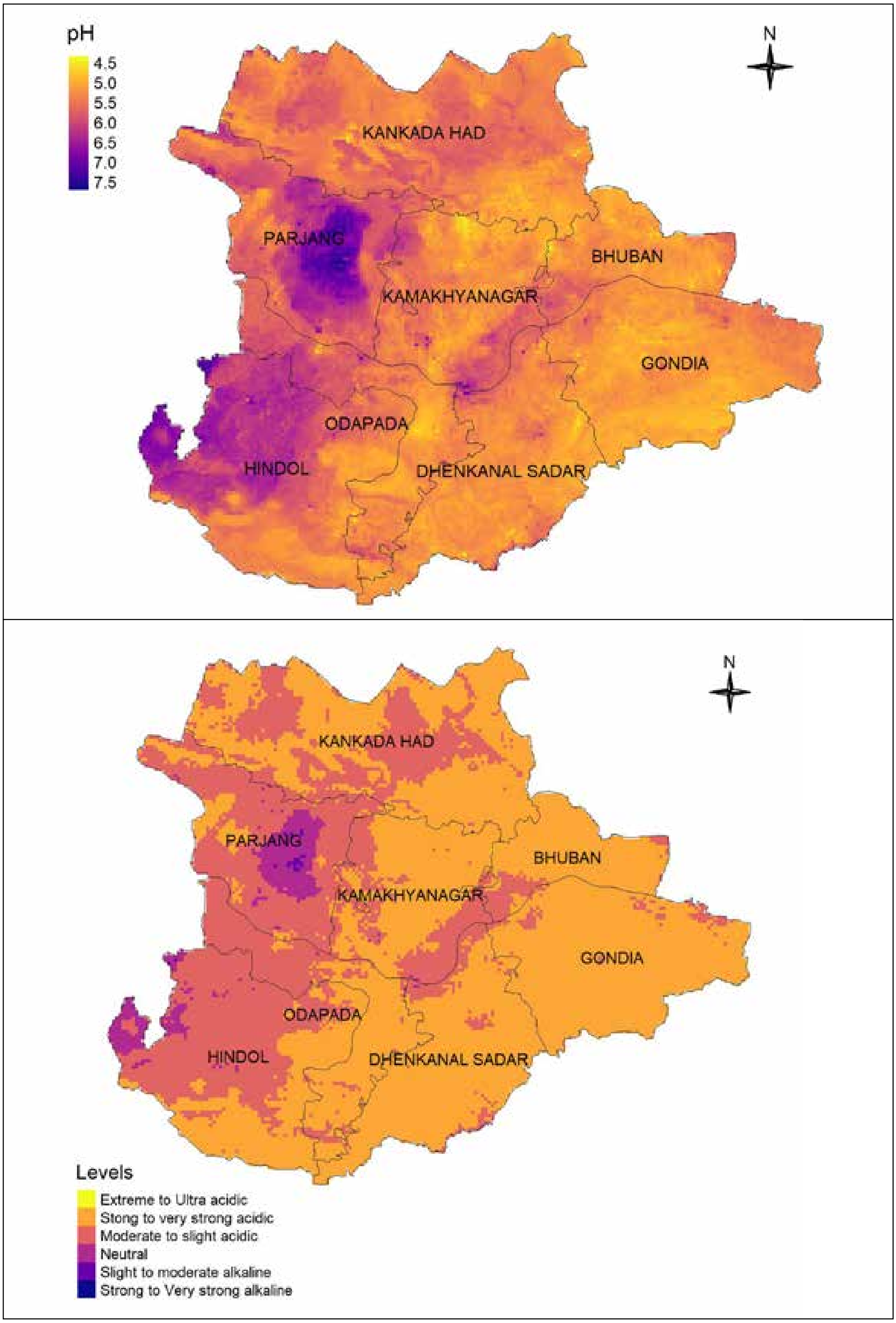


Figure 5.90. pH status in soils of Dhenkanal district.

Electrical conductivity

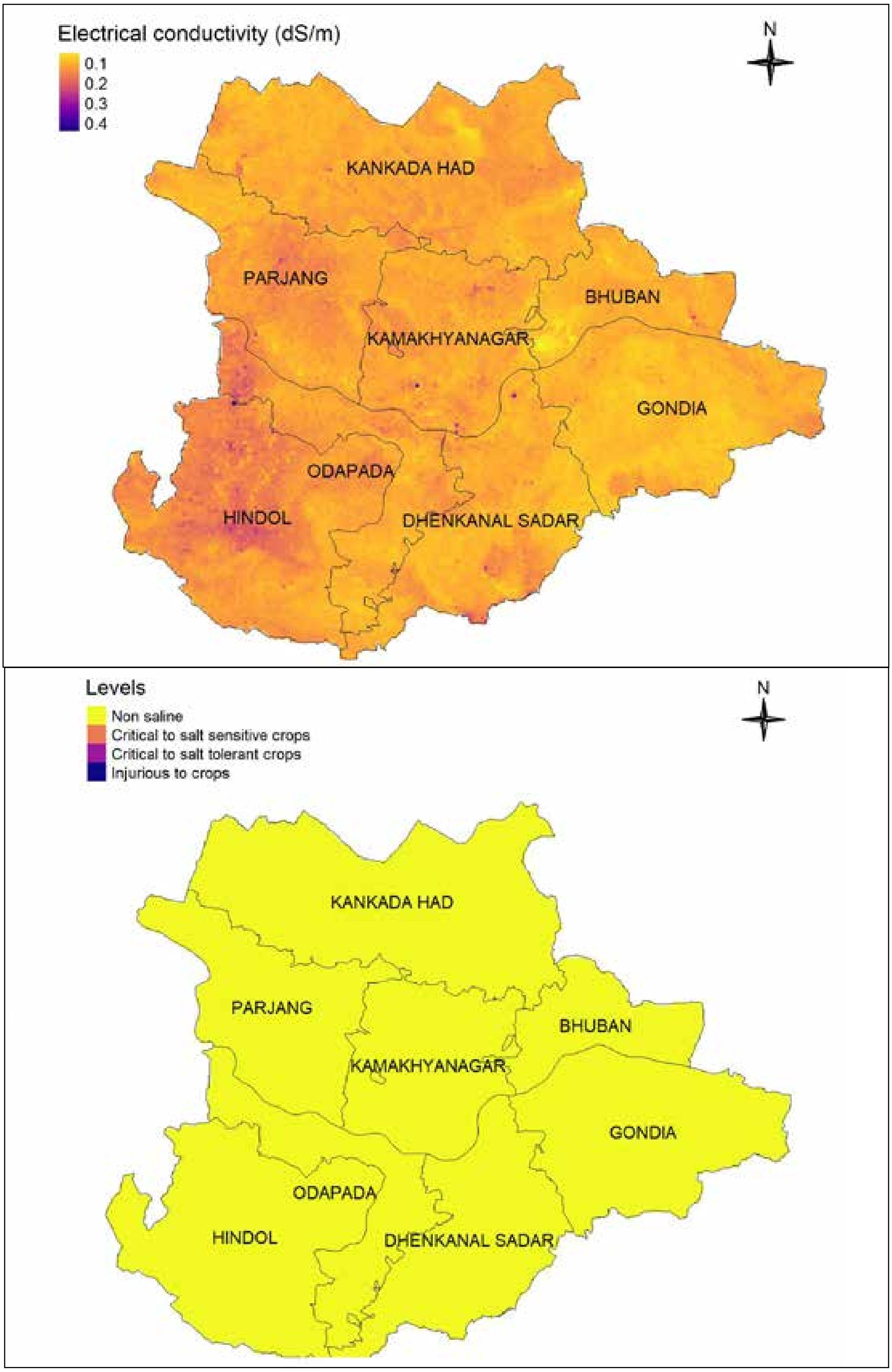


Figure 5.91. Status of electrical conductivity in soils of Dhenkanal district.

Organic carbon

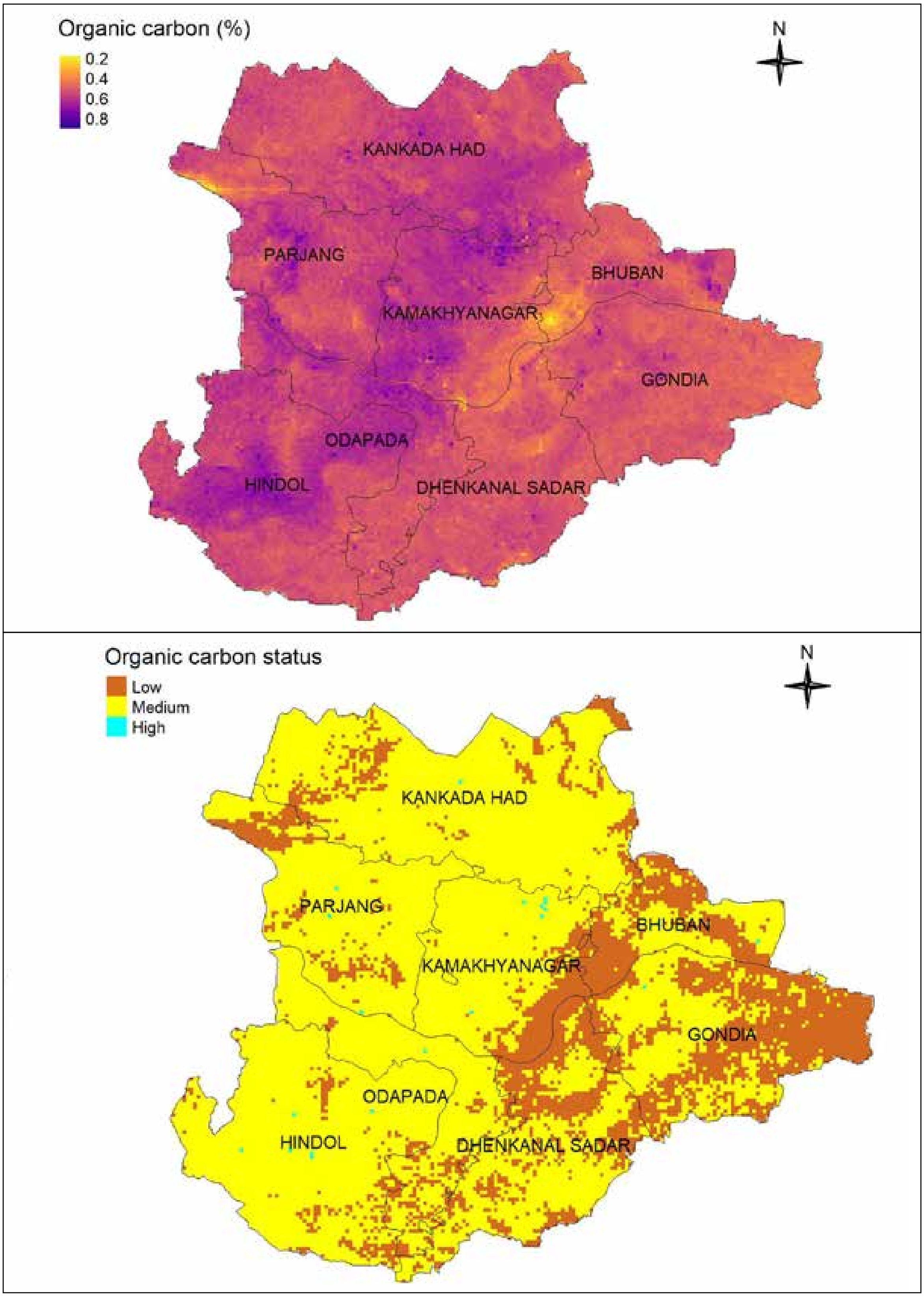


Figure 5.92. Organic carbon status in soils of Dhenkanal district.

Available Phosphorous

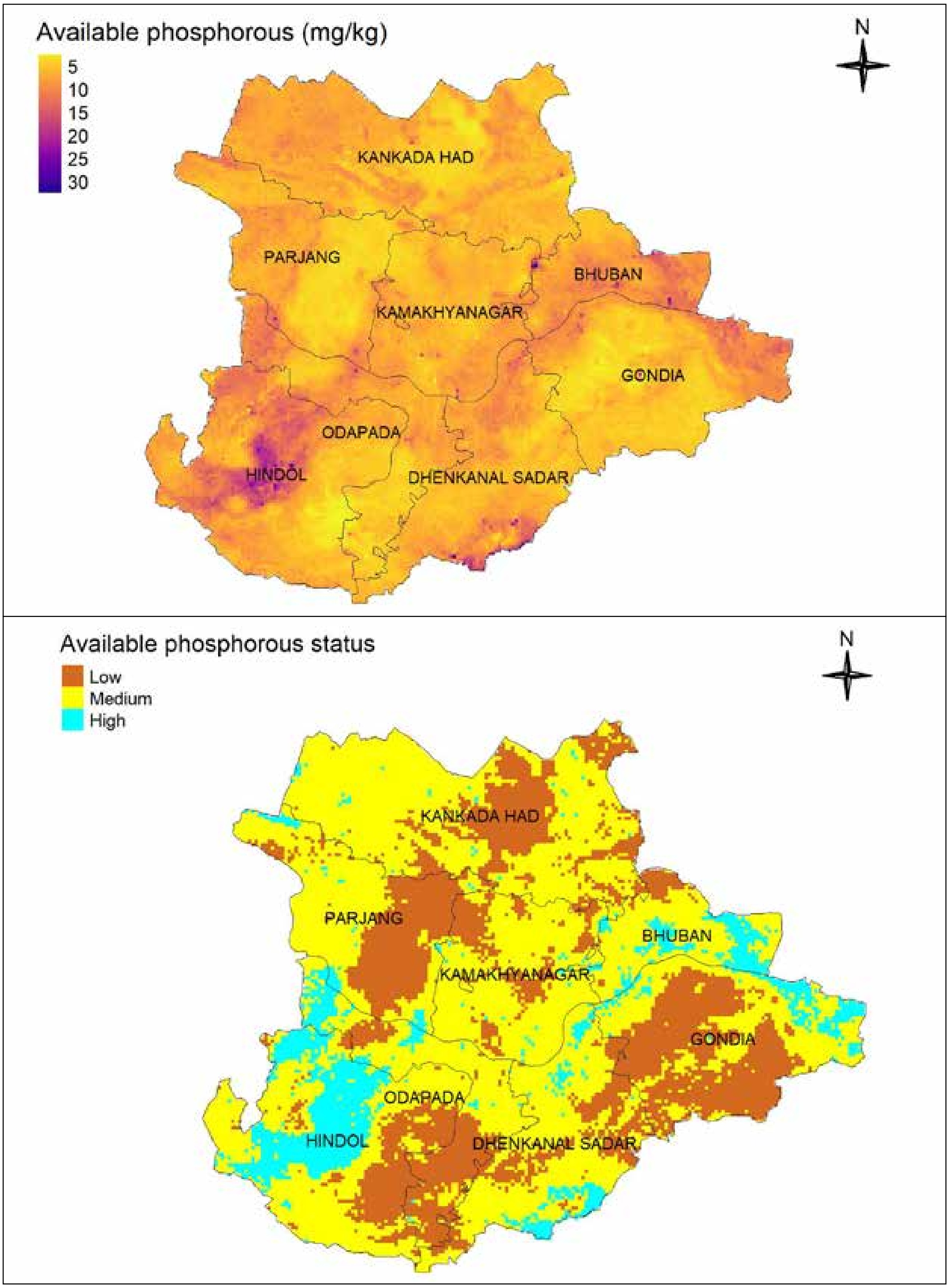
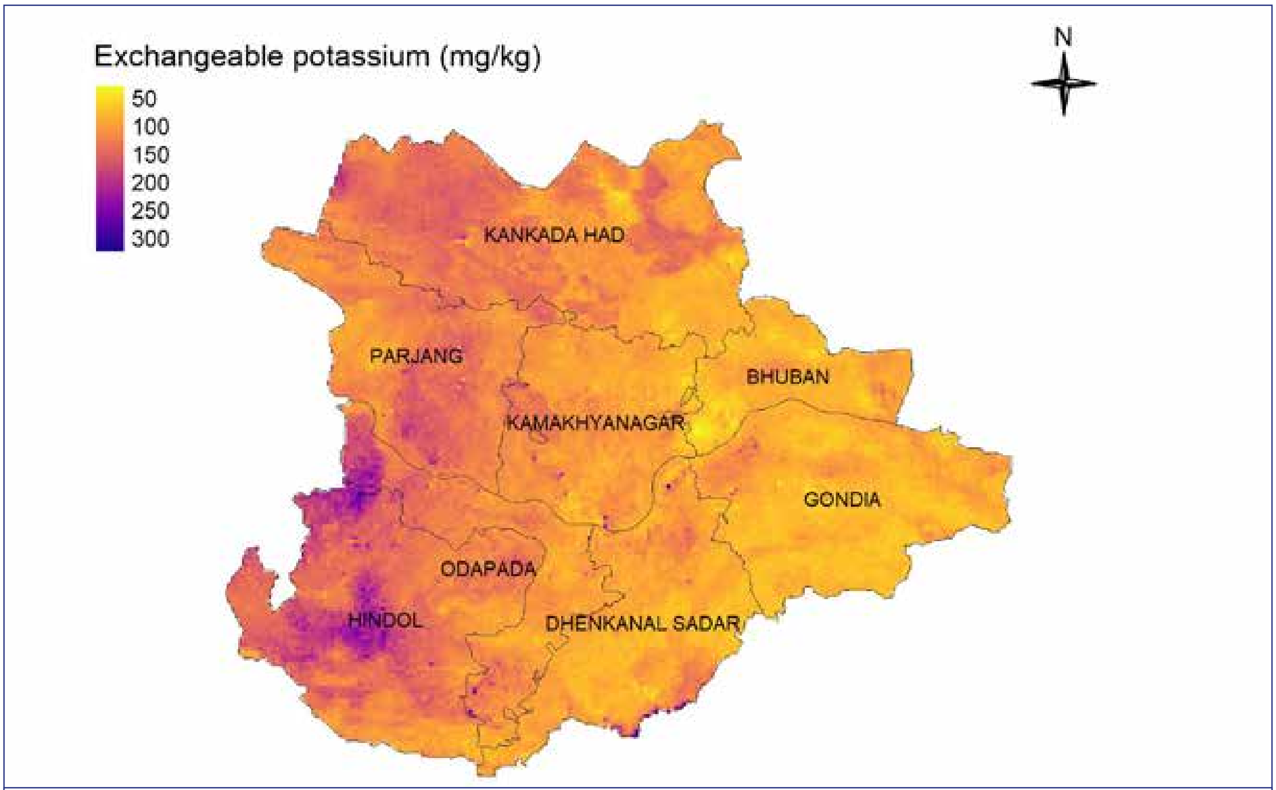


Figure 5.93. Status of available phosphorous in soils of Dhenkanal district.

Exchangeable Potassium



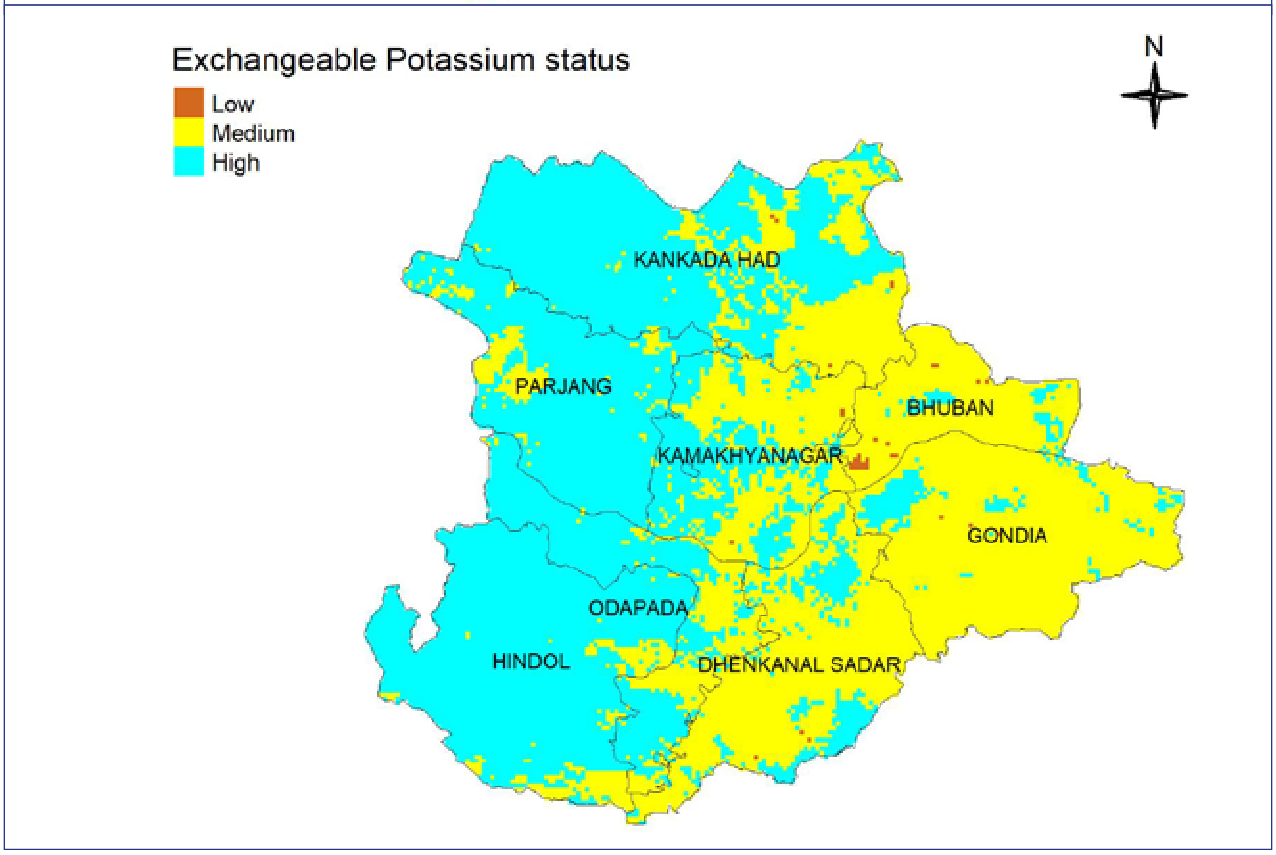


Figure 5.94. Status of exchangeable potassium in soils of Dhenkanal district.

Available Sulfur

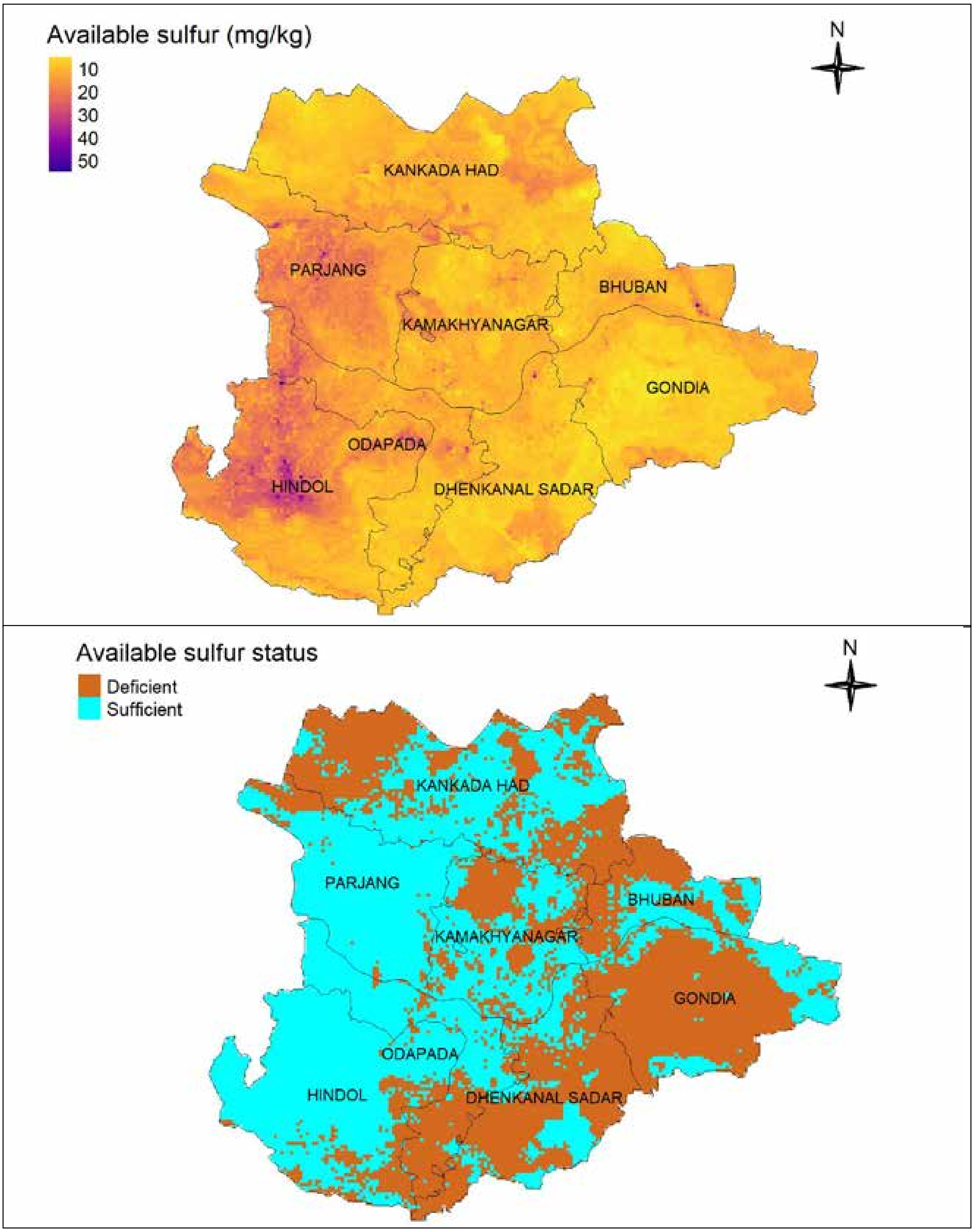


Figure 5.95. Status of available sulfur in soils of Dhenkanal district.

Available Boron

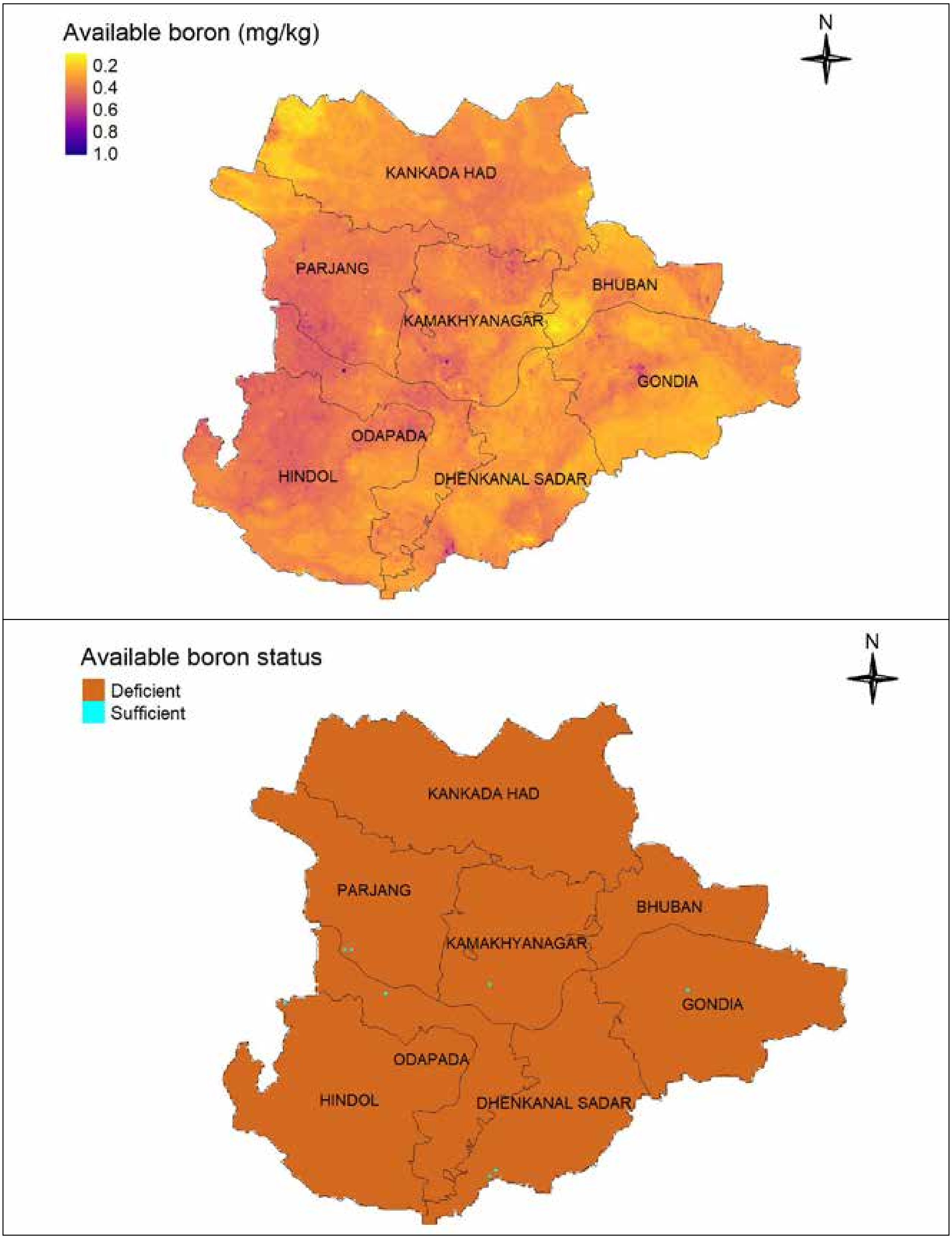


Figure 5.96. Status of available boron in soils of Dhenkanal district.

Available Zinc

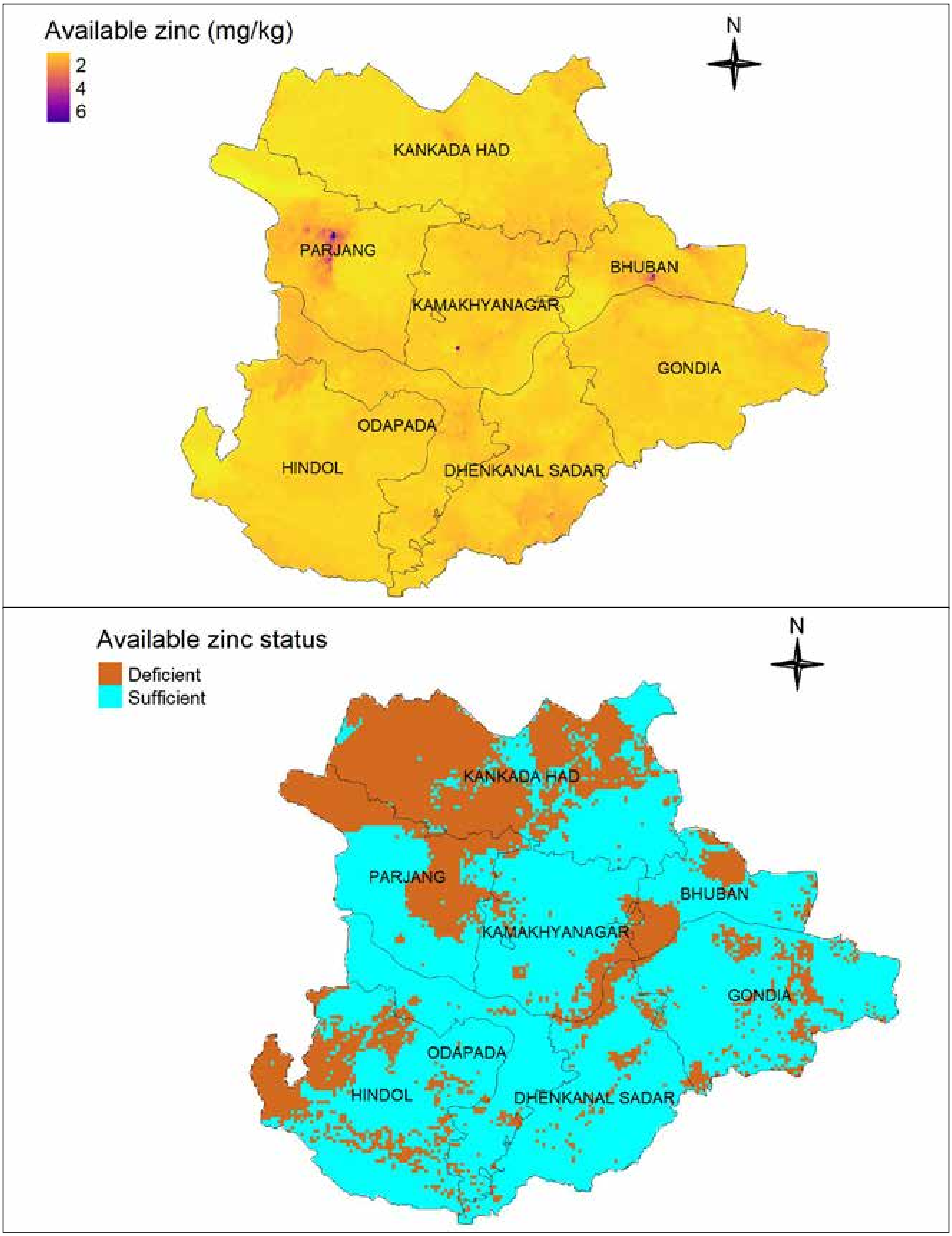


Figure 5.97. Status of available zinc in soils of Dhenkanal district.

Gajapati | pH

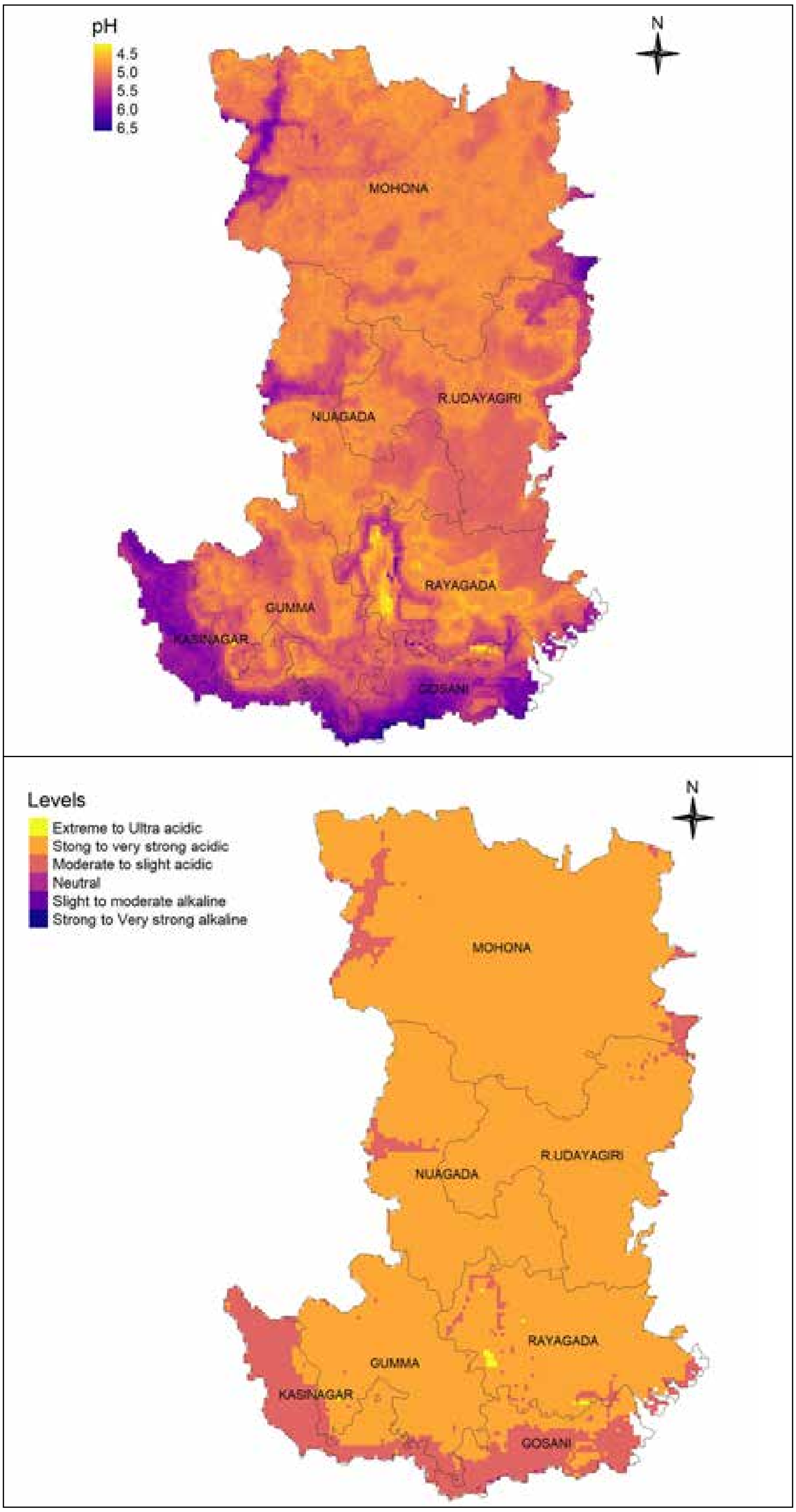


Figure 5.98. pH status in soils of Gajapati district.

Electrical conductivity

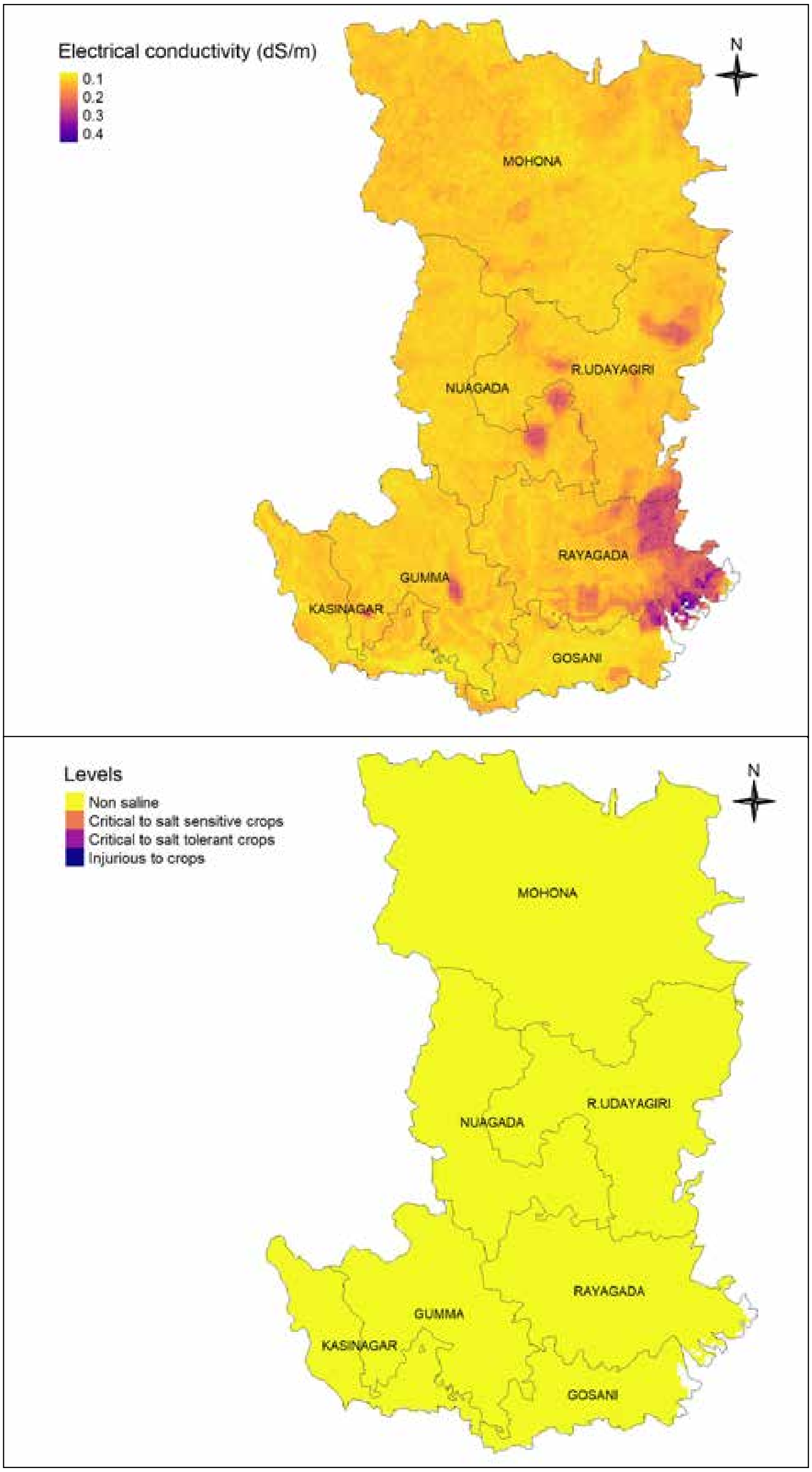


Figure 5.99. Status of electrical conductivity in soils of Gajapati district.

Organic carbon

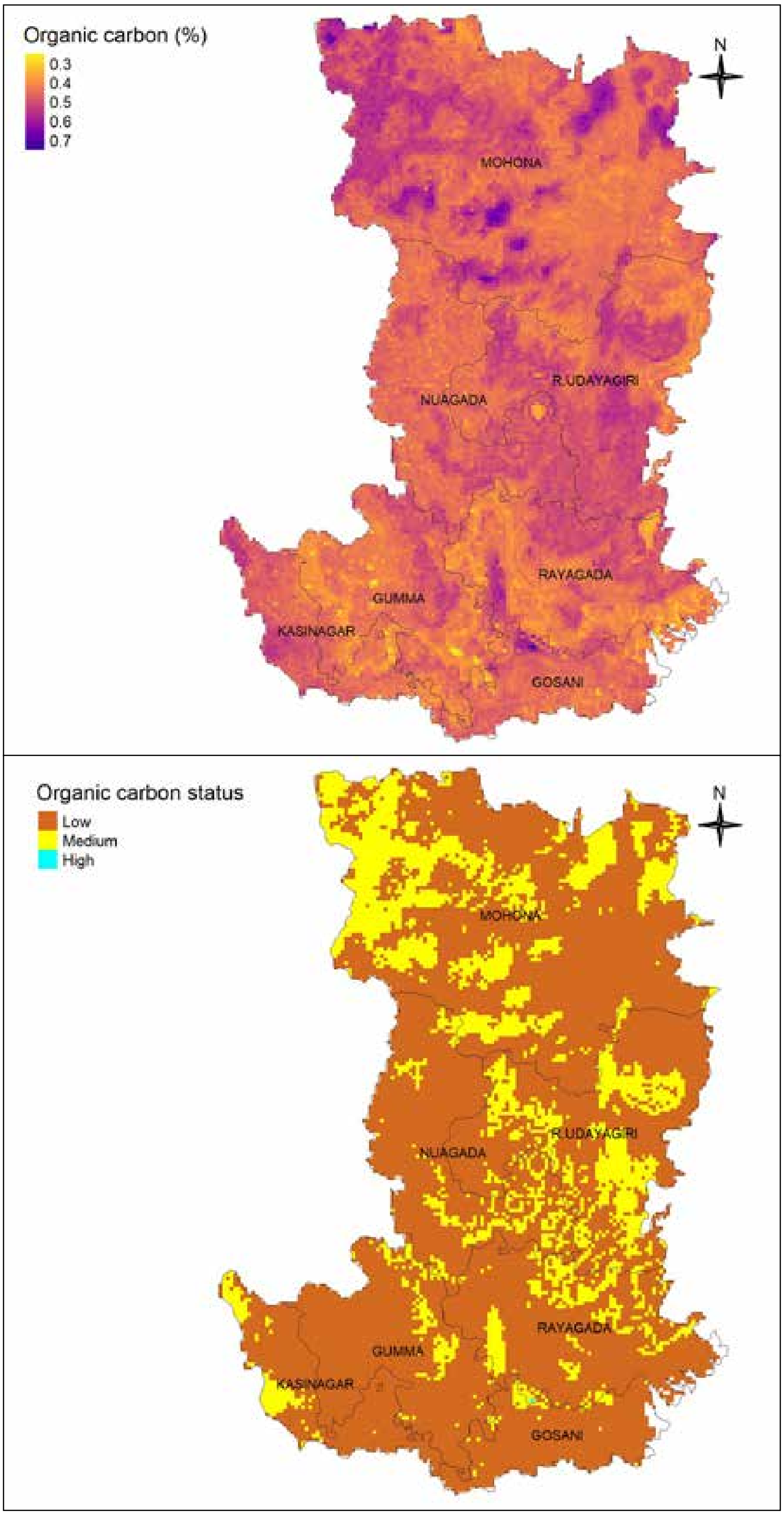


Figure 5.100. Organic carbon status in soils of Gajapati district.

Available Phosphorous

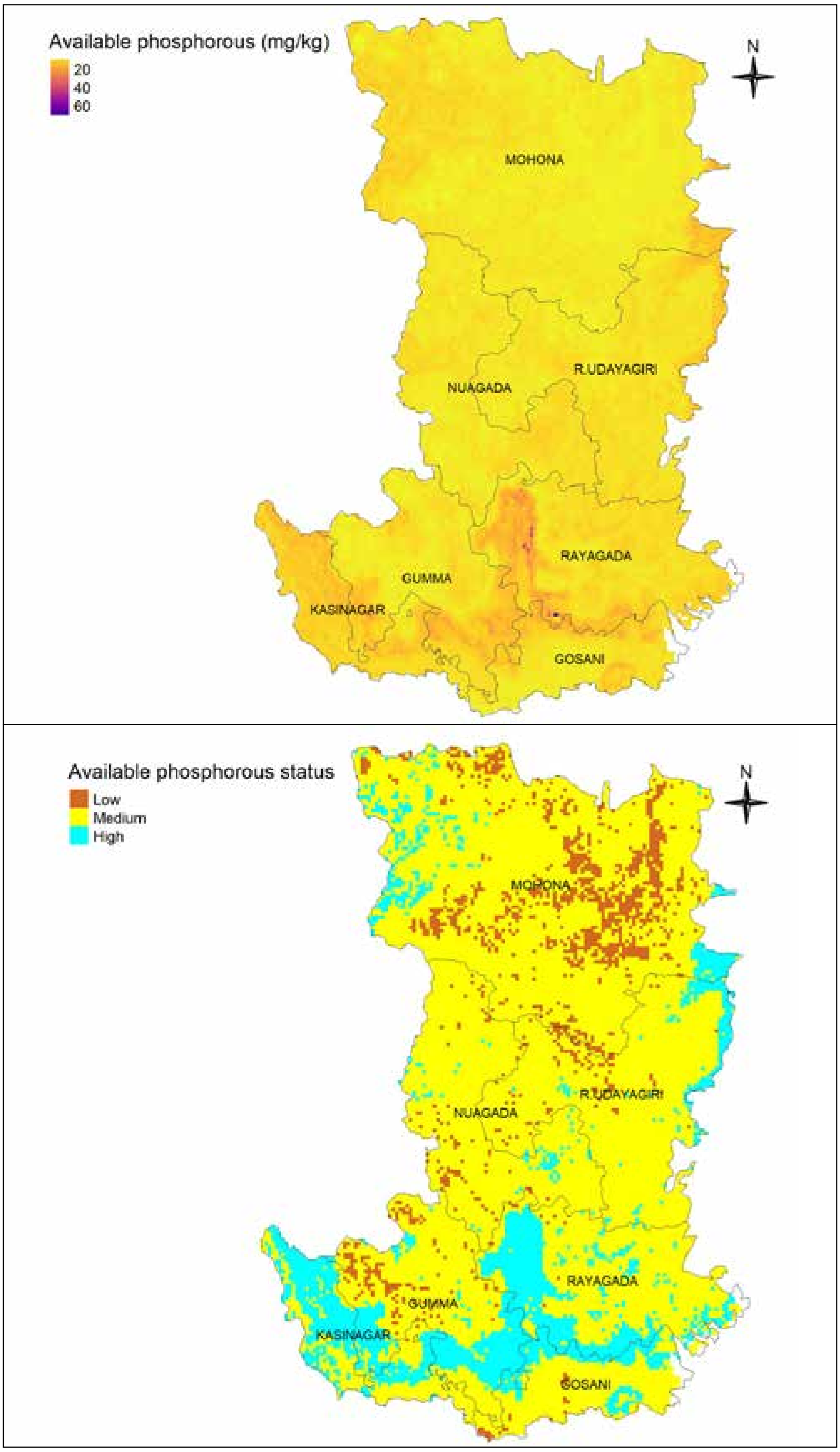


Figure 5.101. Status of available phosphorous in soils of Gajapati district.

Exchangeable Potassium

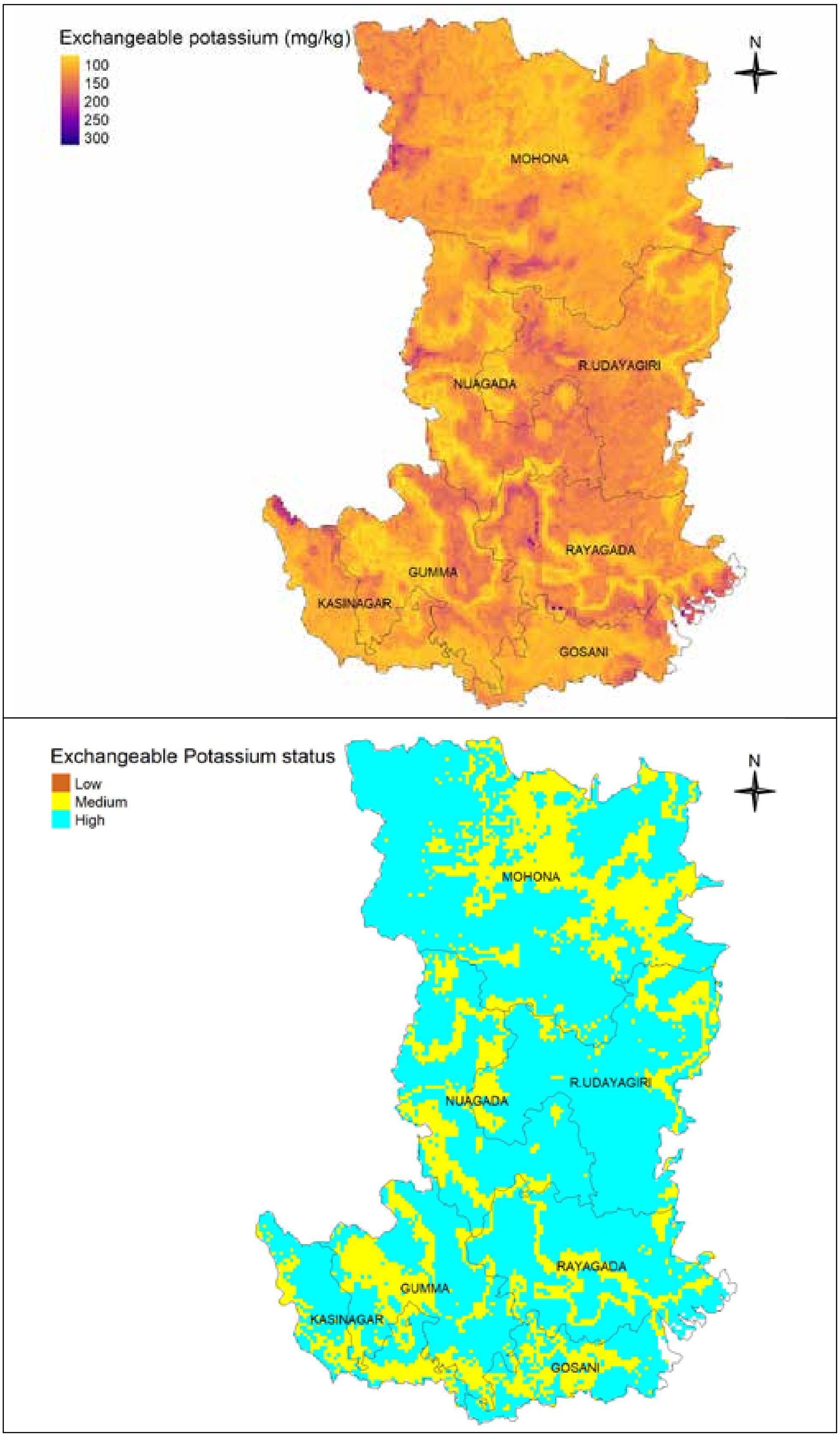


Figure 5.102. Status of exchangeable potassium in soils of Gajapati district.

Available Sulfur

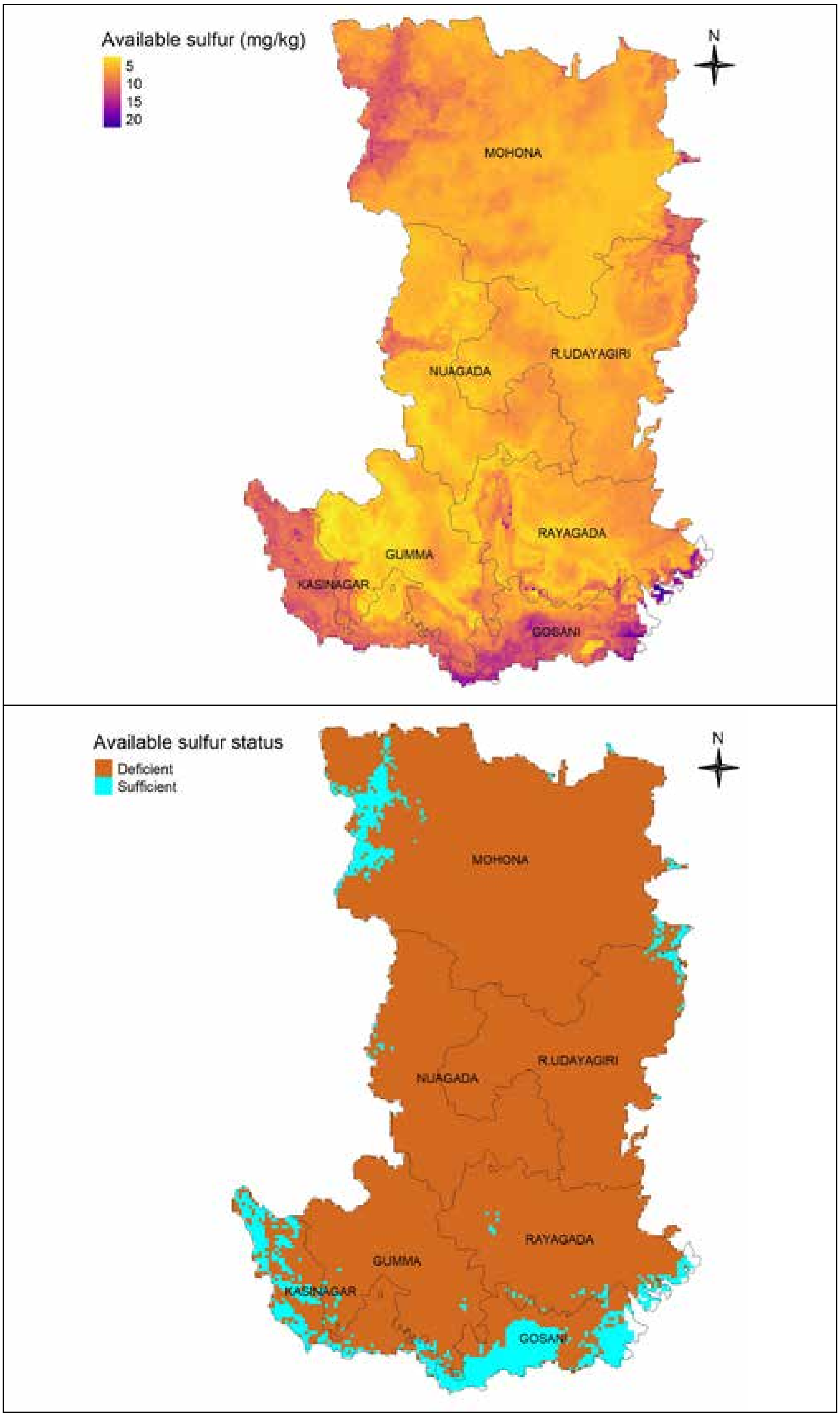


Figure 5.103. Status of available sulfur in soils of Gajapati district.

Available Boron

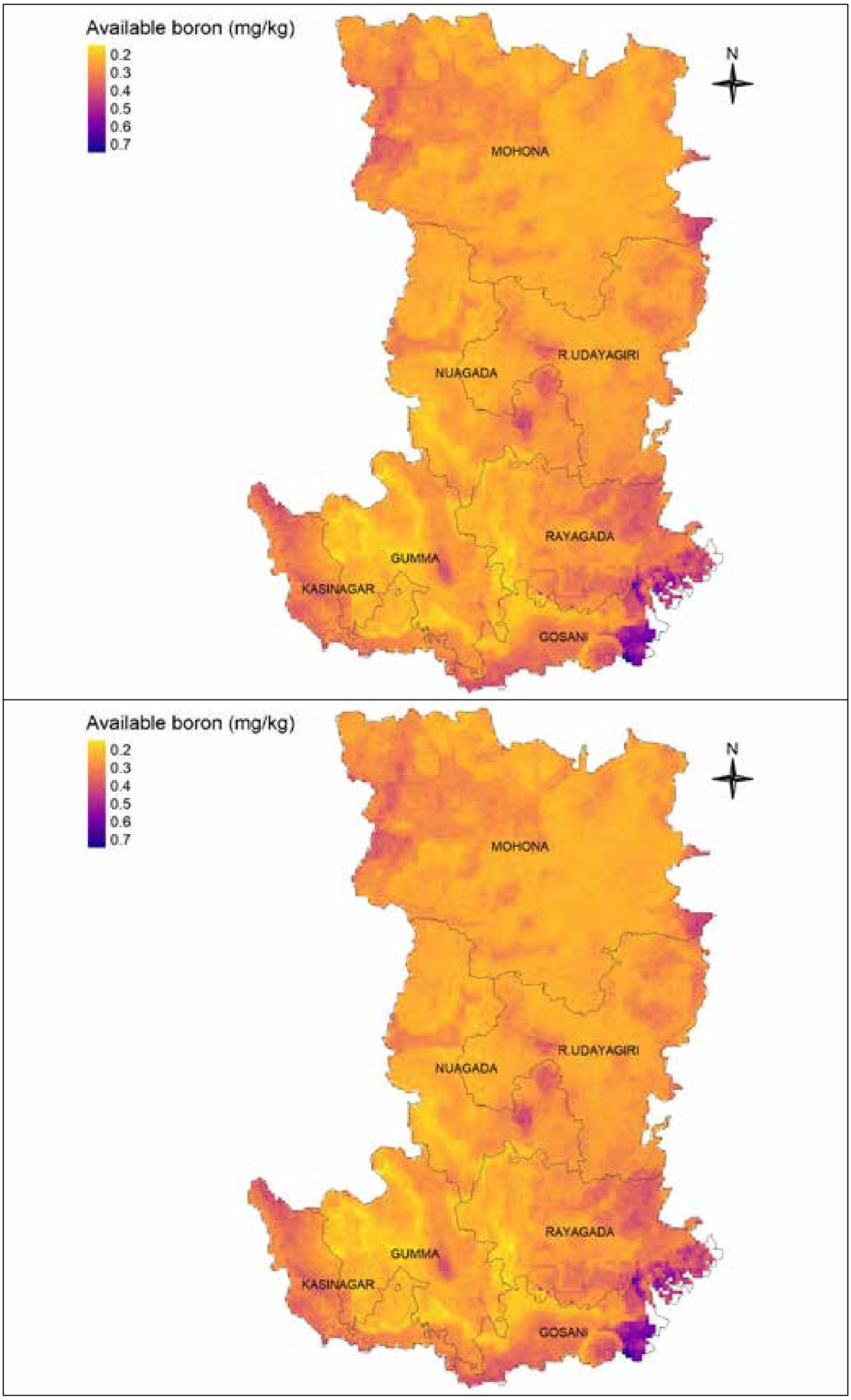


Figure 5.104. Status of available boron in soils of Gajapati district.

Available Zinc

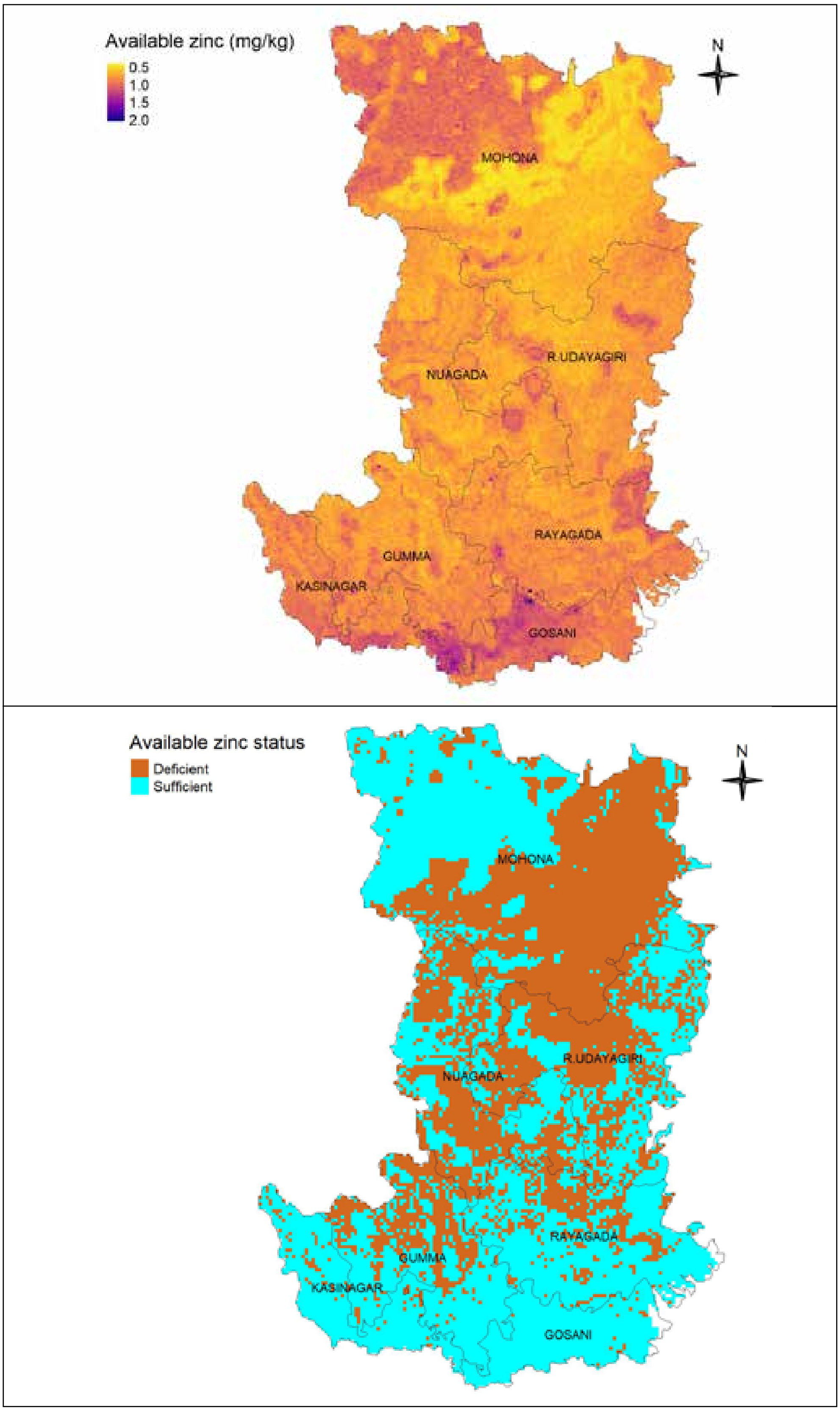


Figure 5.105. Status of available zinc in soils of Gajapati district.

Ganjam | pH

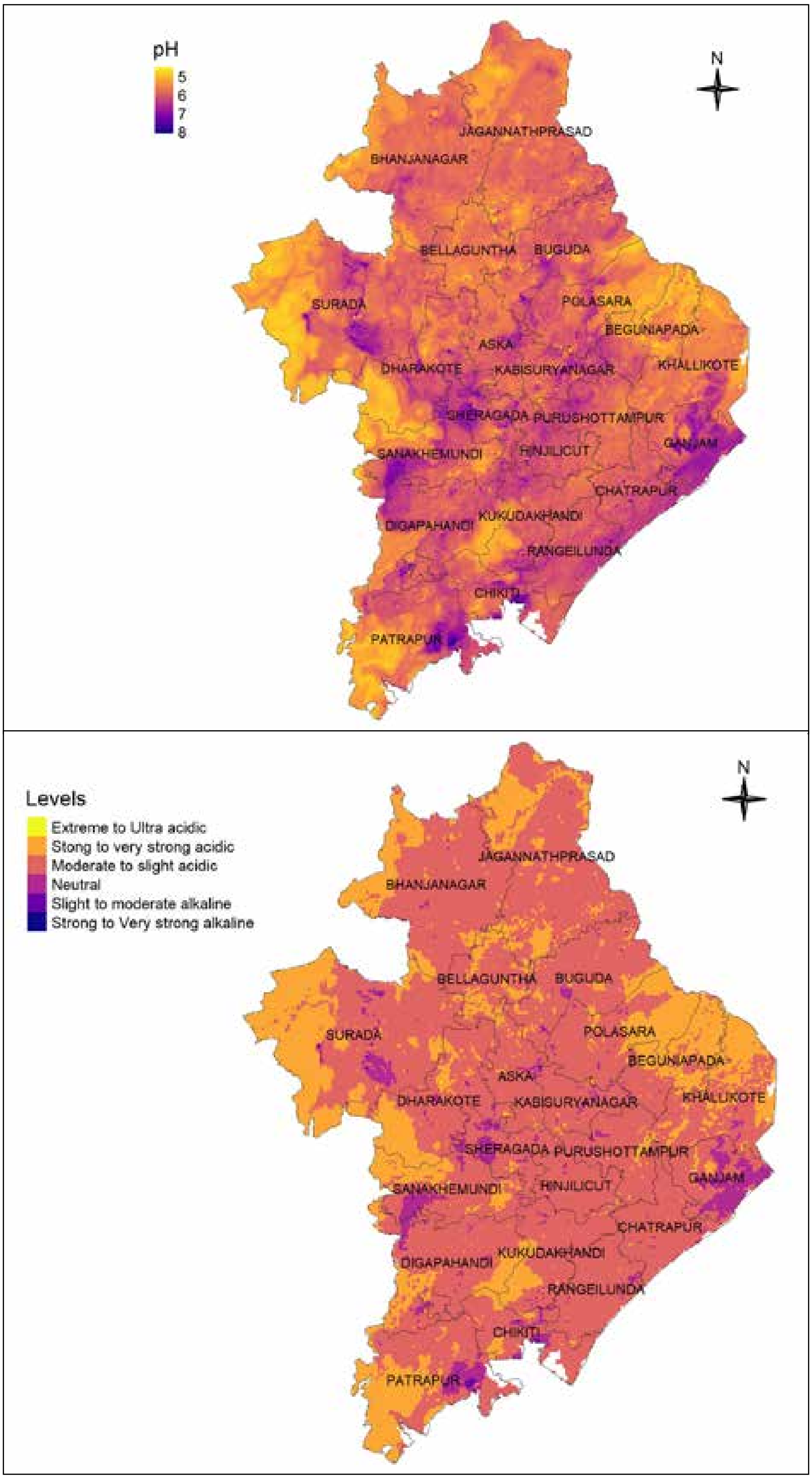


Figure 5.106. pH status in soils of Ganjam district.

Electrical conductivity

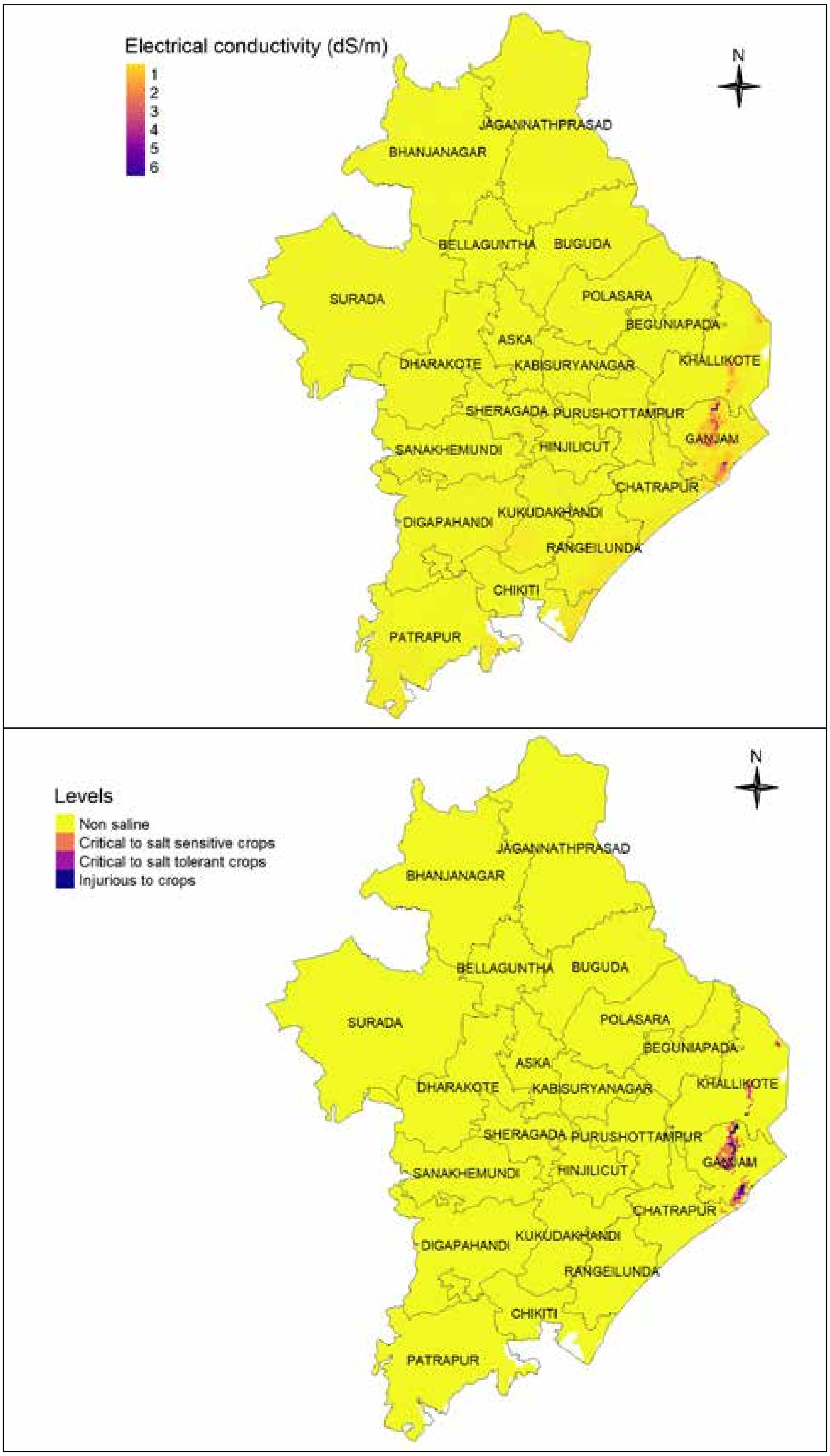


Figure 5.107. Status of electrical conductivity in soils of Ganjam district.

Organic carbon

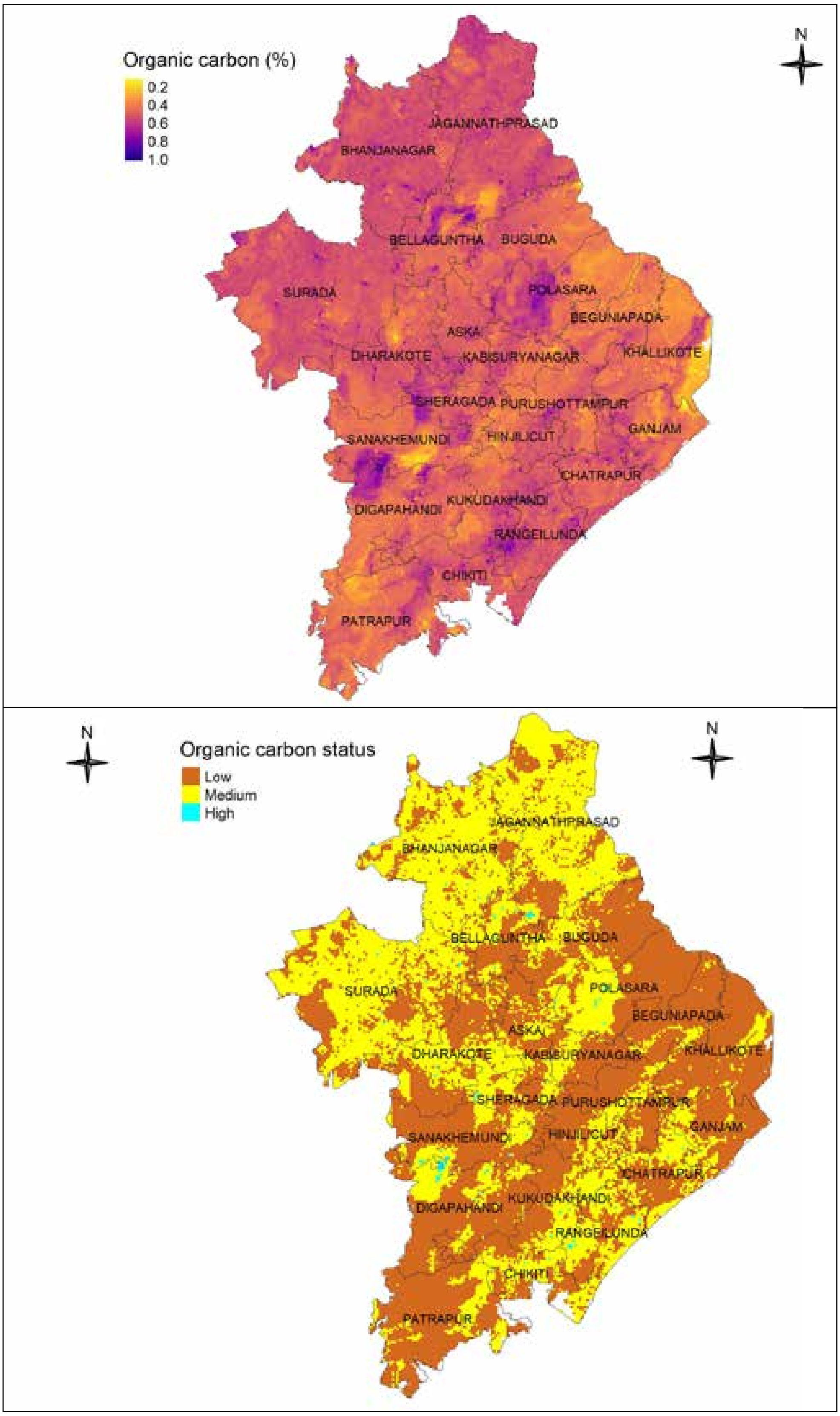


Figure 5.108. Organic carbon status in soils of Ganjam district.

Available Phosphorous

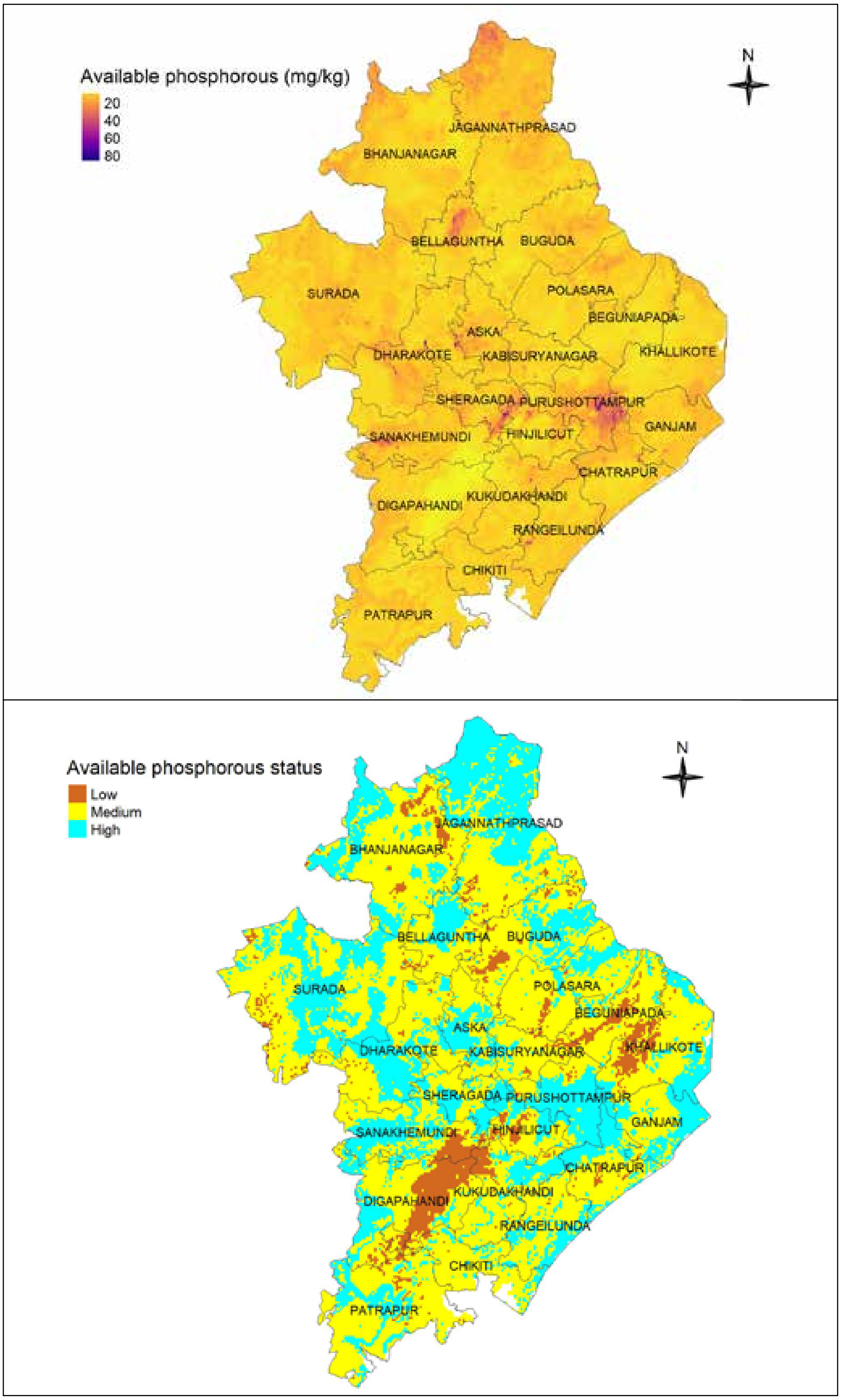


Figure 5.109. Status of available phosphorous in soils of Ganjam district.

Exchangeable Potassium

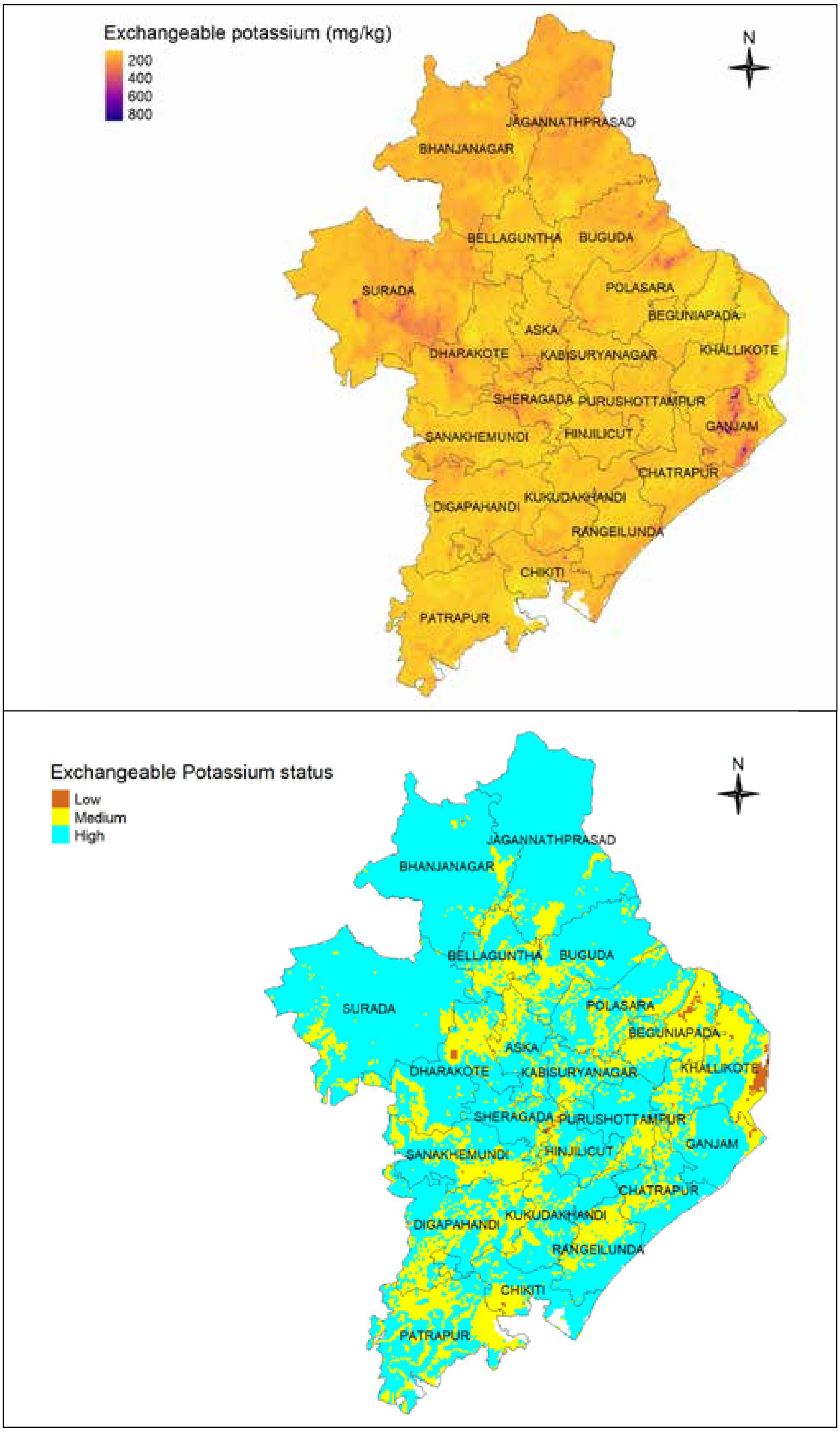


Figure 5.110. Status of exchangeable potassium in soils of Ganjam district.

Available Sulfur

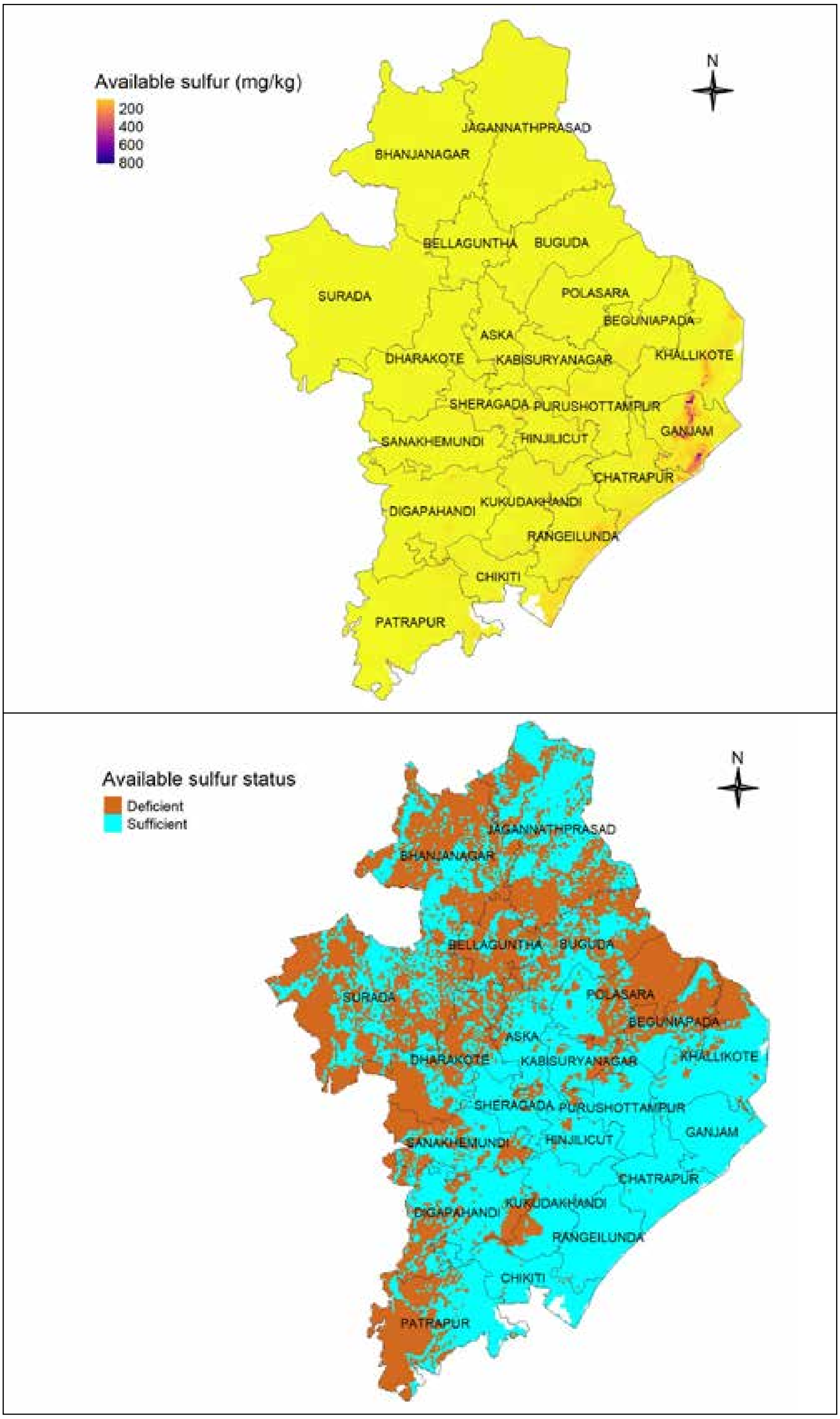


Figure 5.111. Status of available sulfur in soils of Ganjam district.

Available Boron

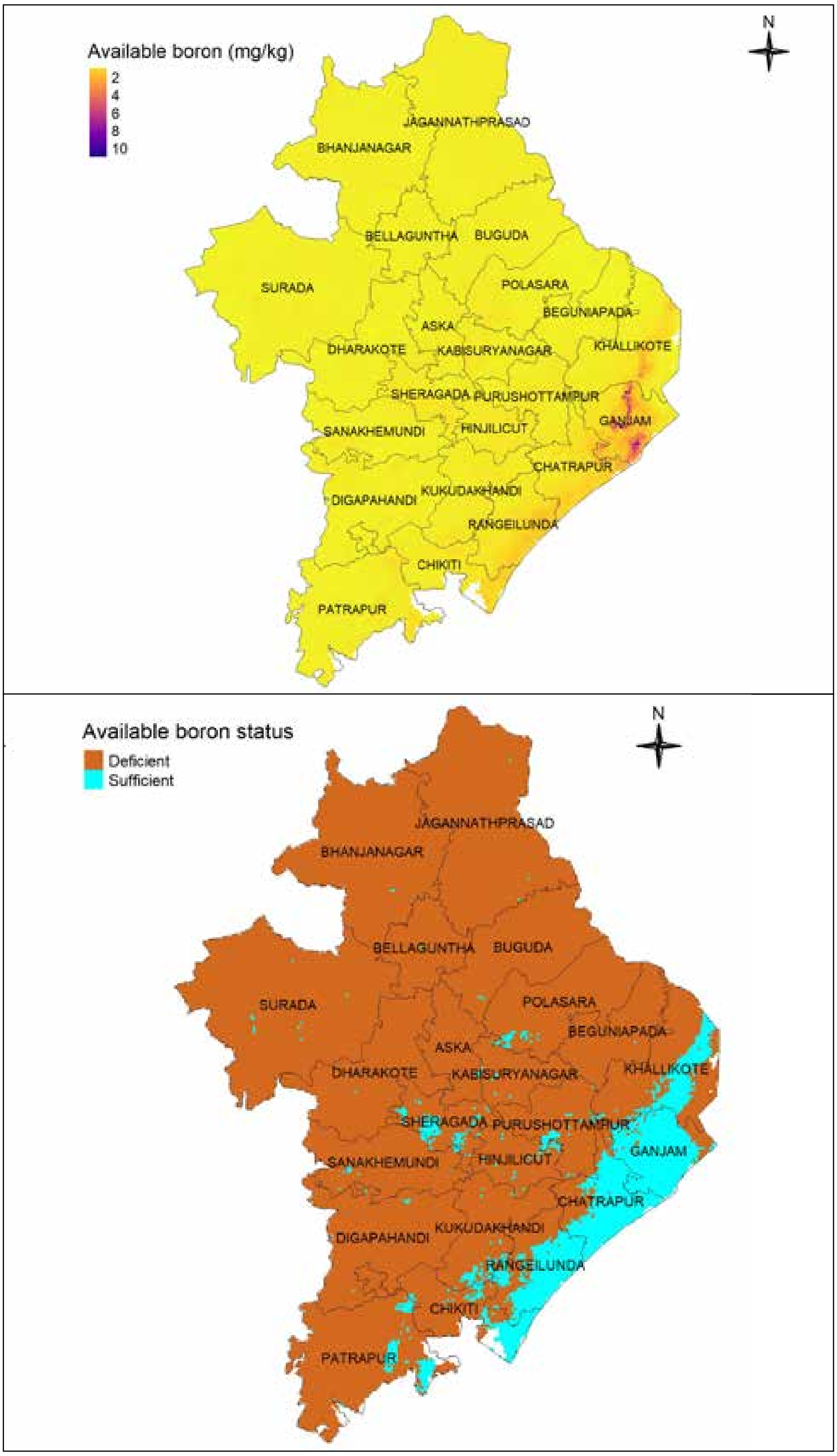


Figure 5.112. Status of available boron in soils of Ganjam district.

Available Zinc

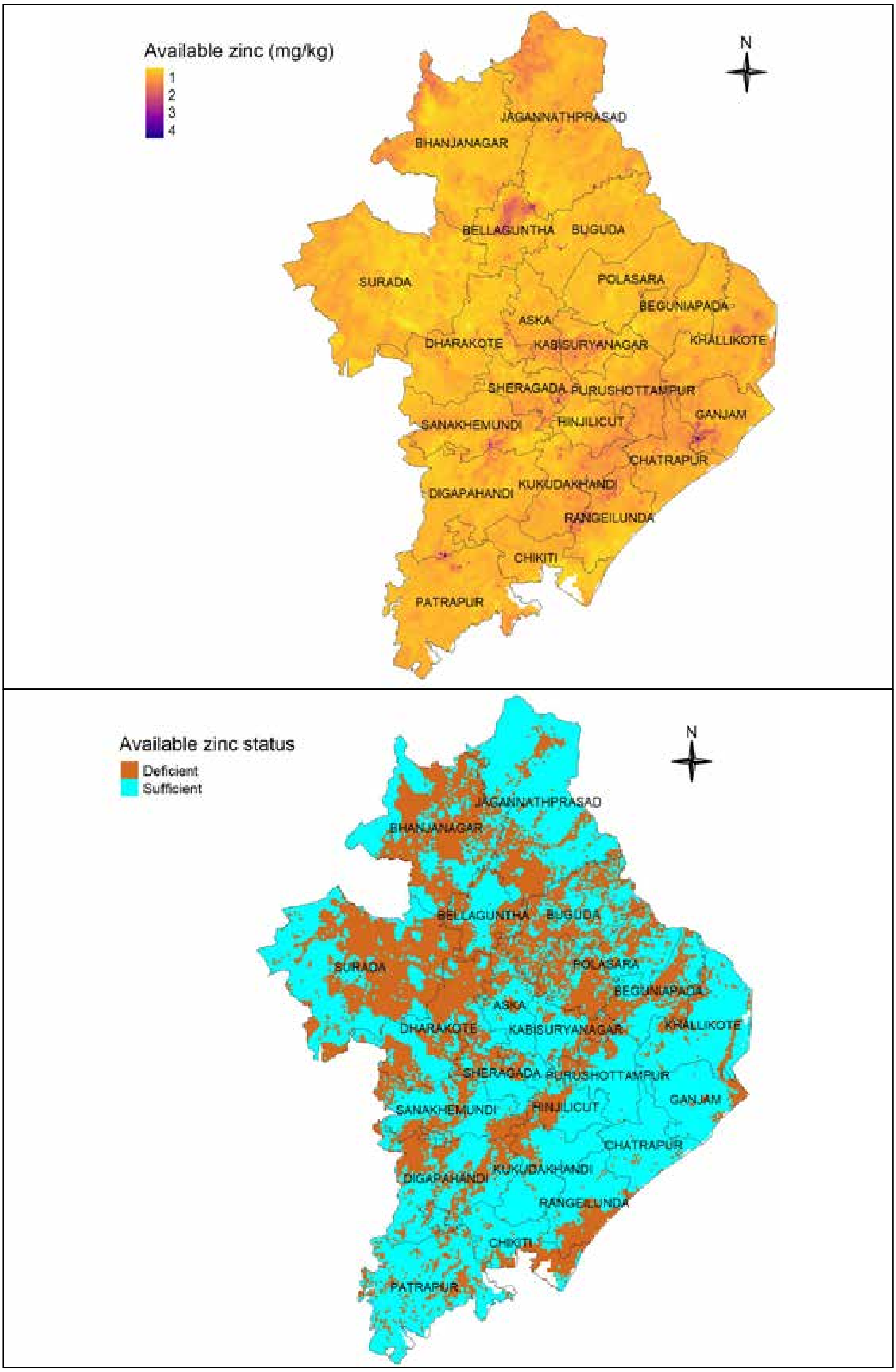


Figure 5.113. Status of available zinc in soils of Ganjam district.

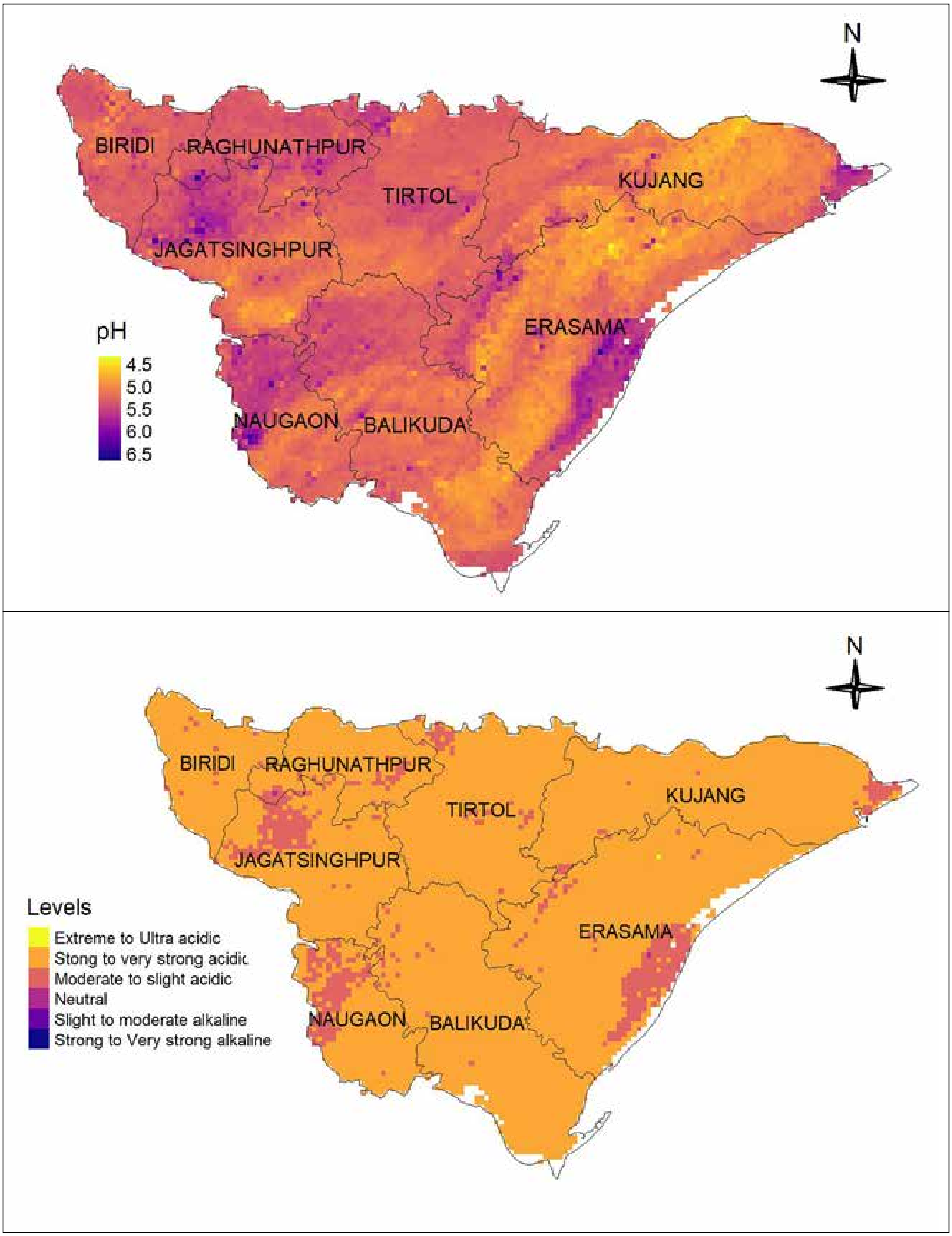


Figure 5.114. pH status in soils of Jagatsinghpur district.

Electrical conductivity

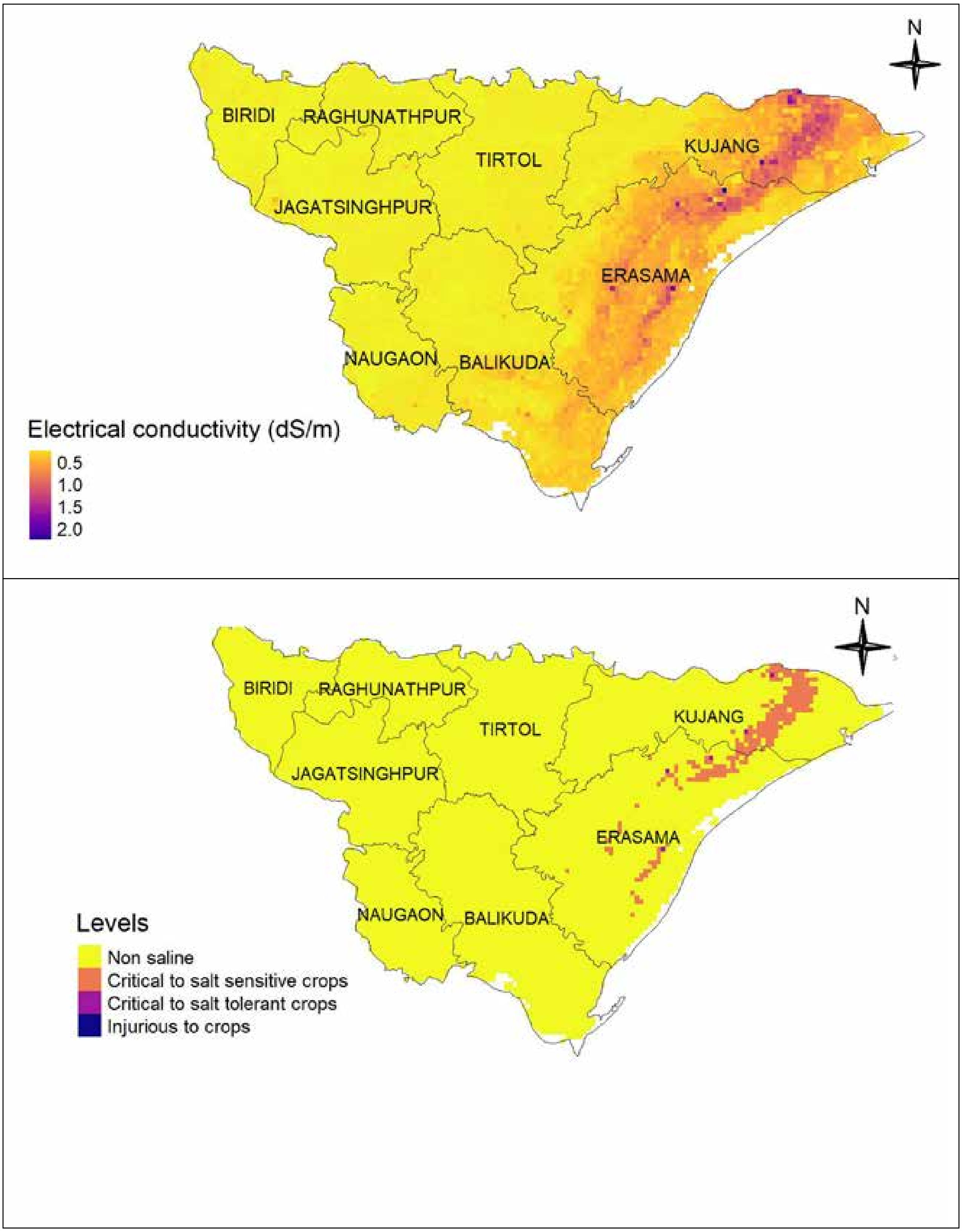


Figure 5.115. Status of electrical conductivity in soils of Jagatsinghpur district.

Organic carbon

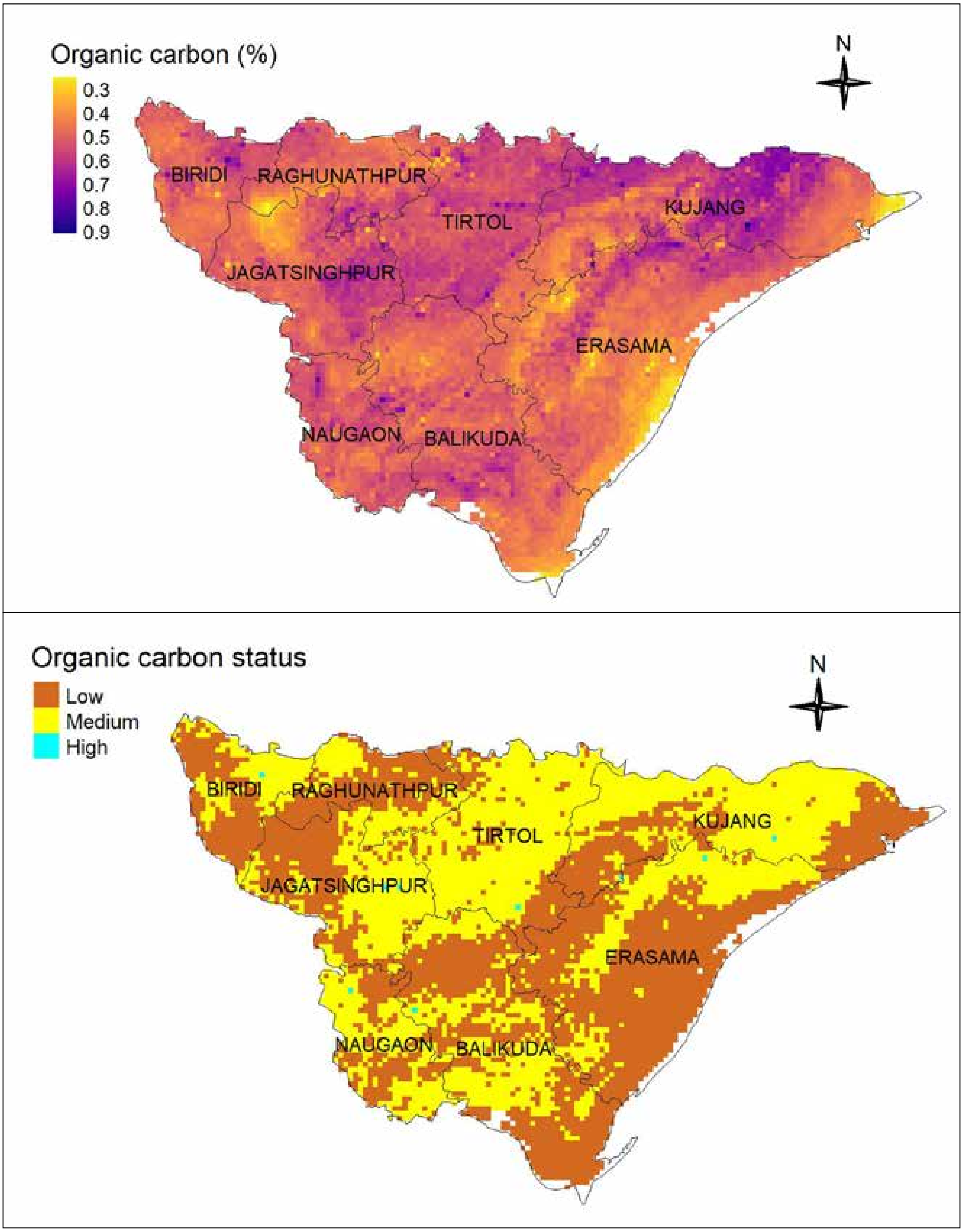


Figure 5.116. Organic carbon status in soils of Jagatsinghpur district.

Available Phosphorous

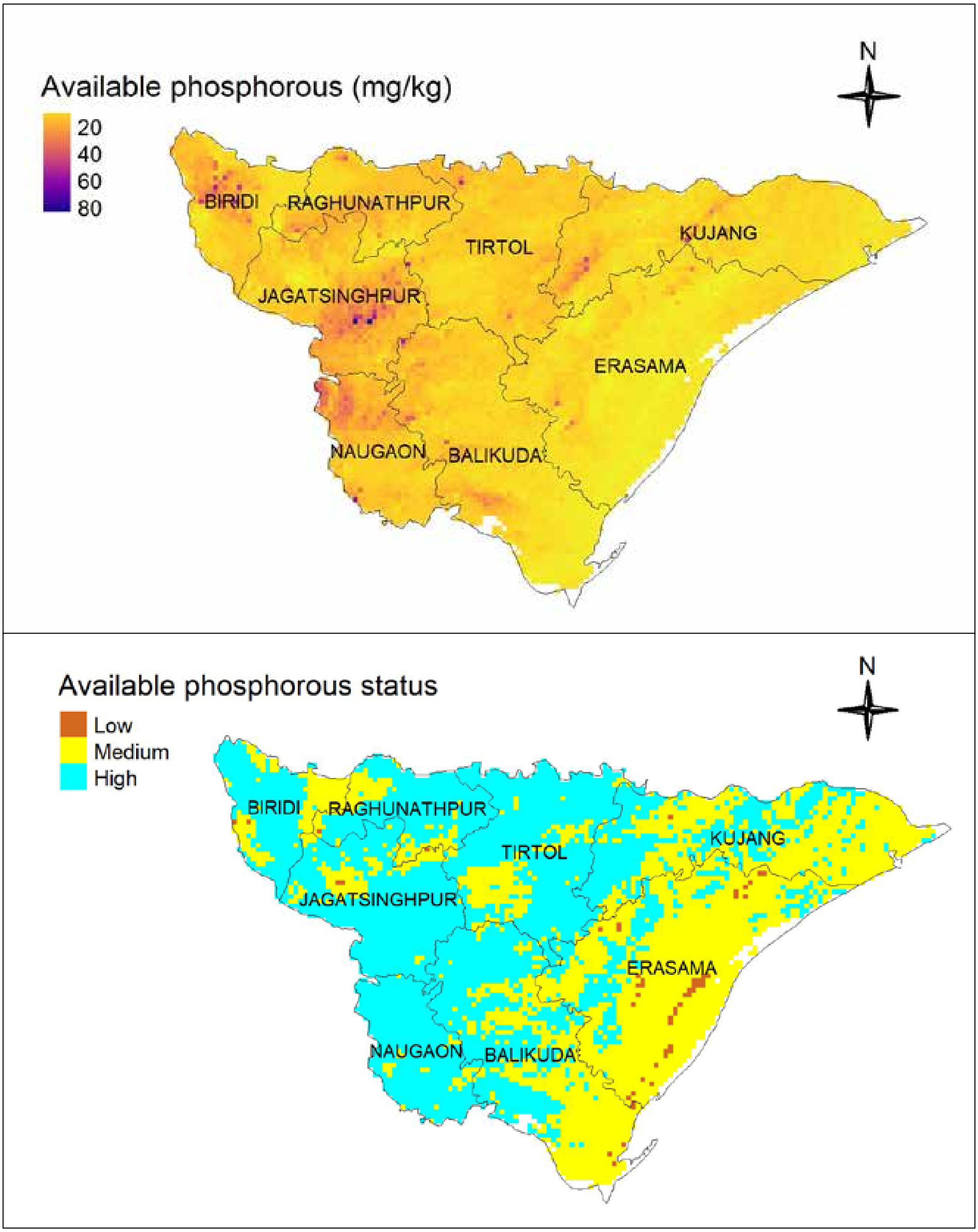


Figure 5.117. Status of available phosphorous in soils of Jagatsinghpur district.

Exchangeable Potassium

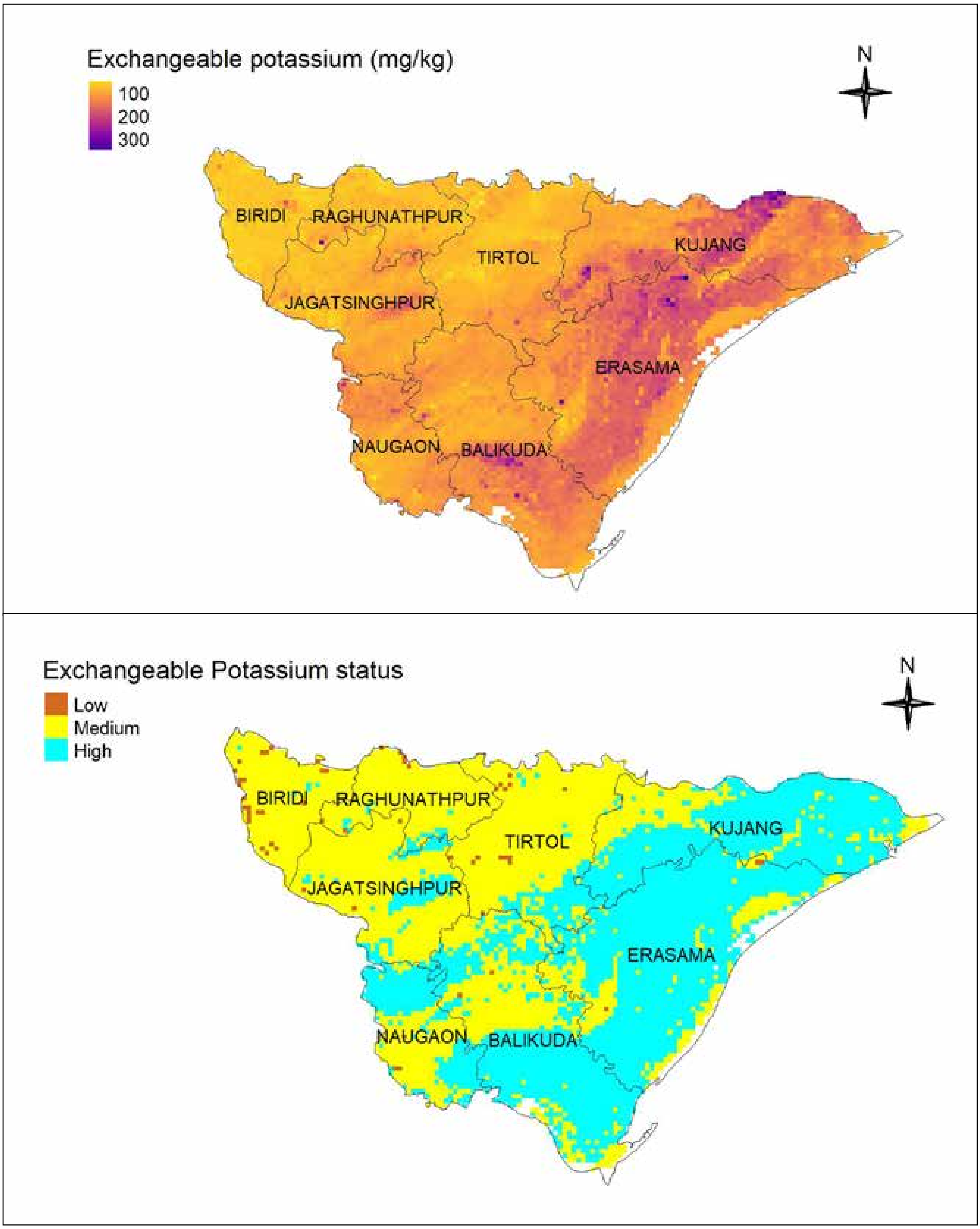


Figure 5.118. Status of exchangeable potassium in soils of Jagatsinghpur district.

Available Sulfur

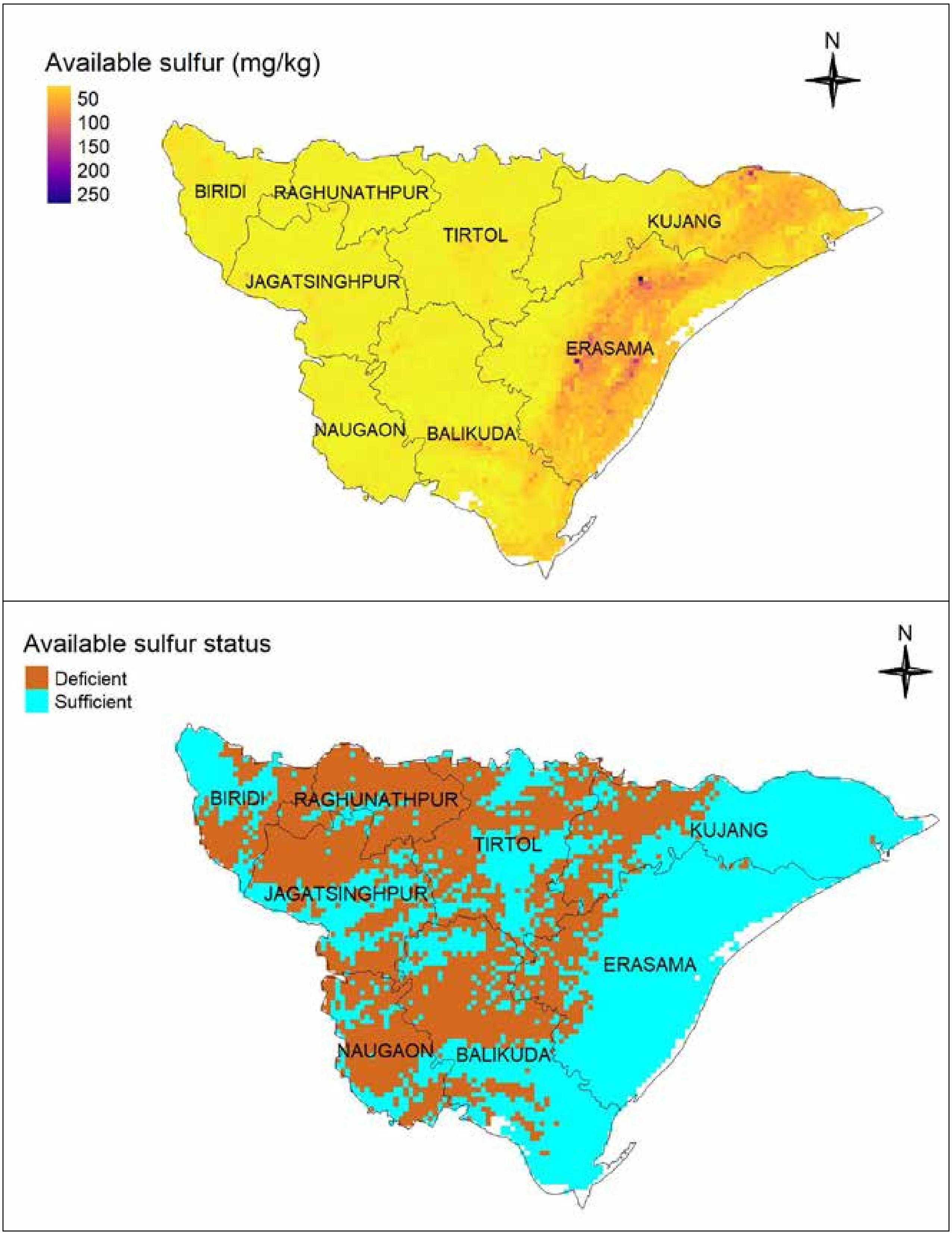


Figure 5.119. Status of available sulfur in soils of Jagatsinghpur district.

Available Boron

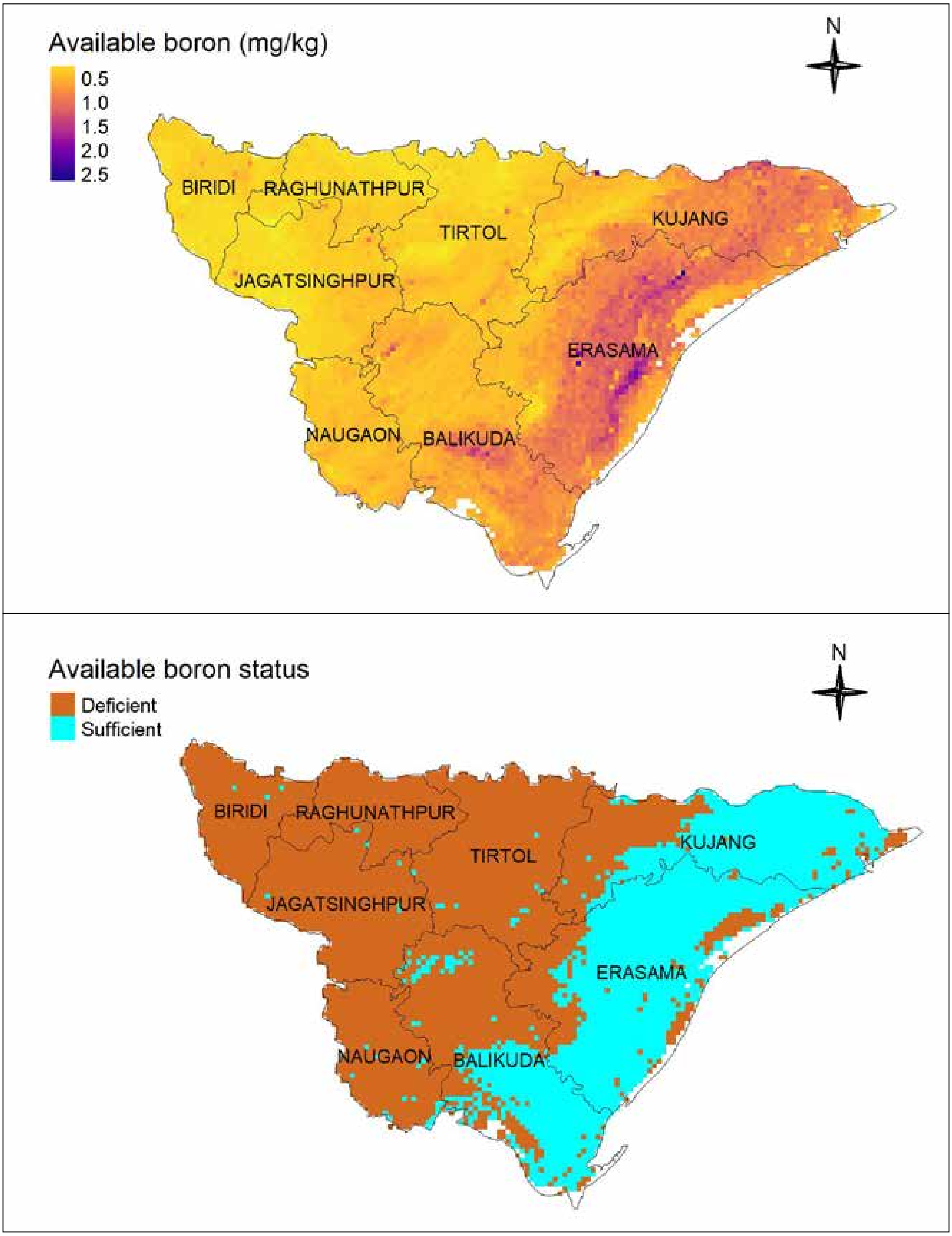


Figure 5.120. Status of available boron in soils of Jagatsinghpur district.

Available Zinc

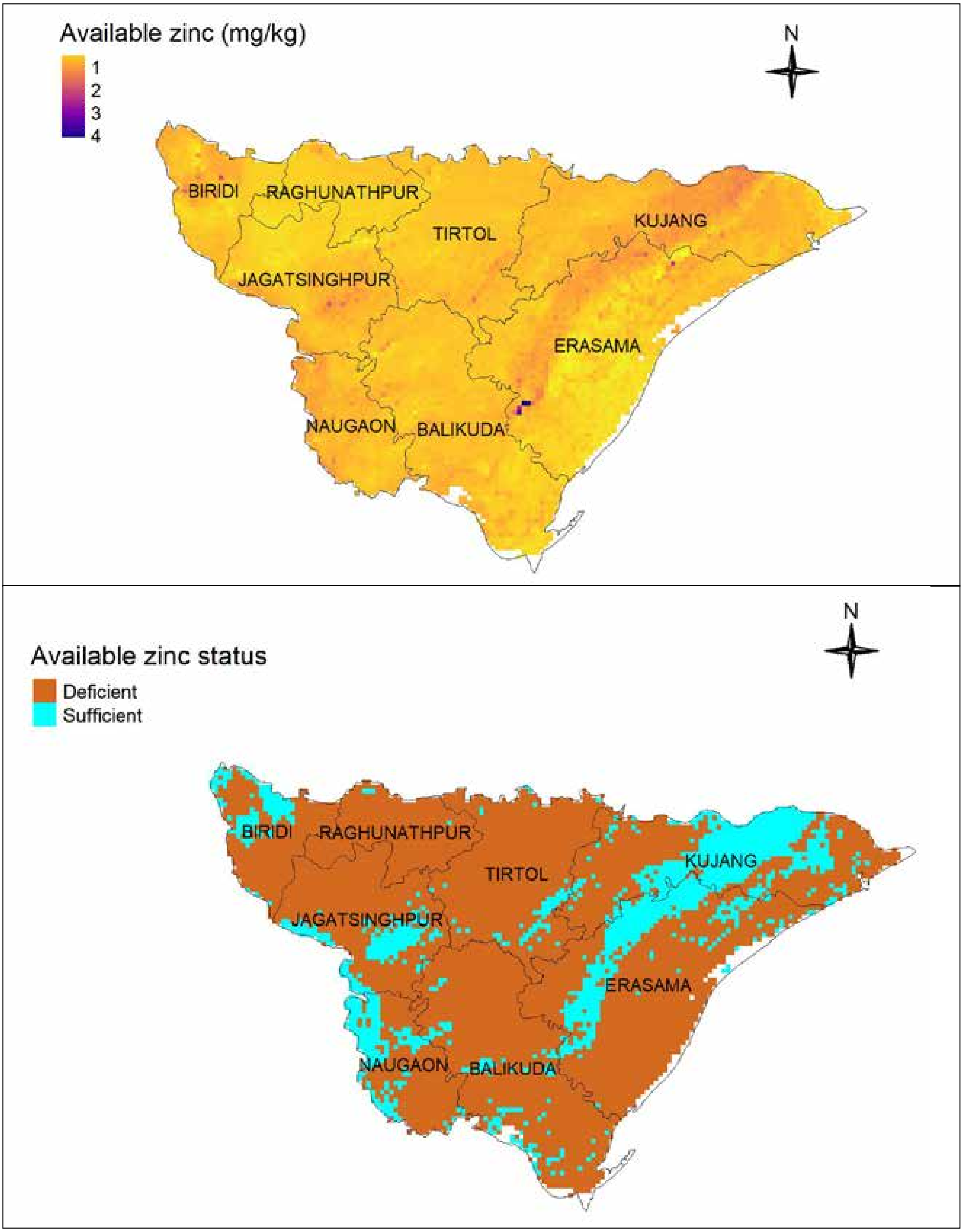


Figure 5.121. Status of available zinc in soils of Jagatsinghpur district.

Jajpur | pH

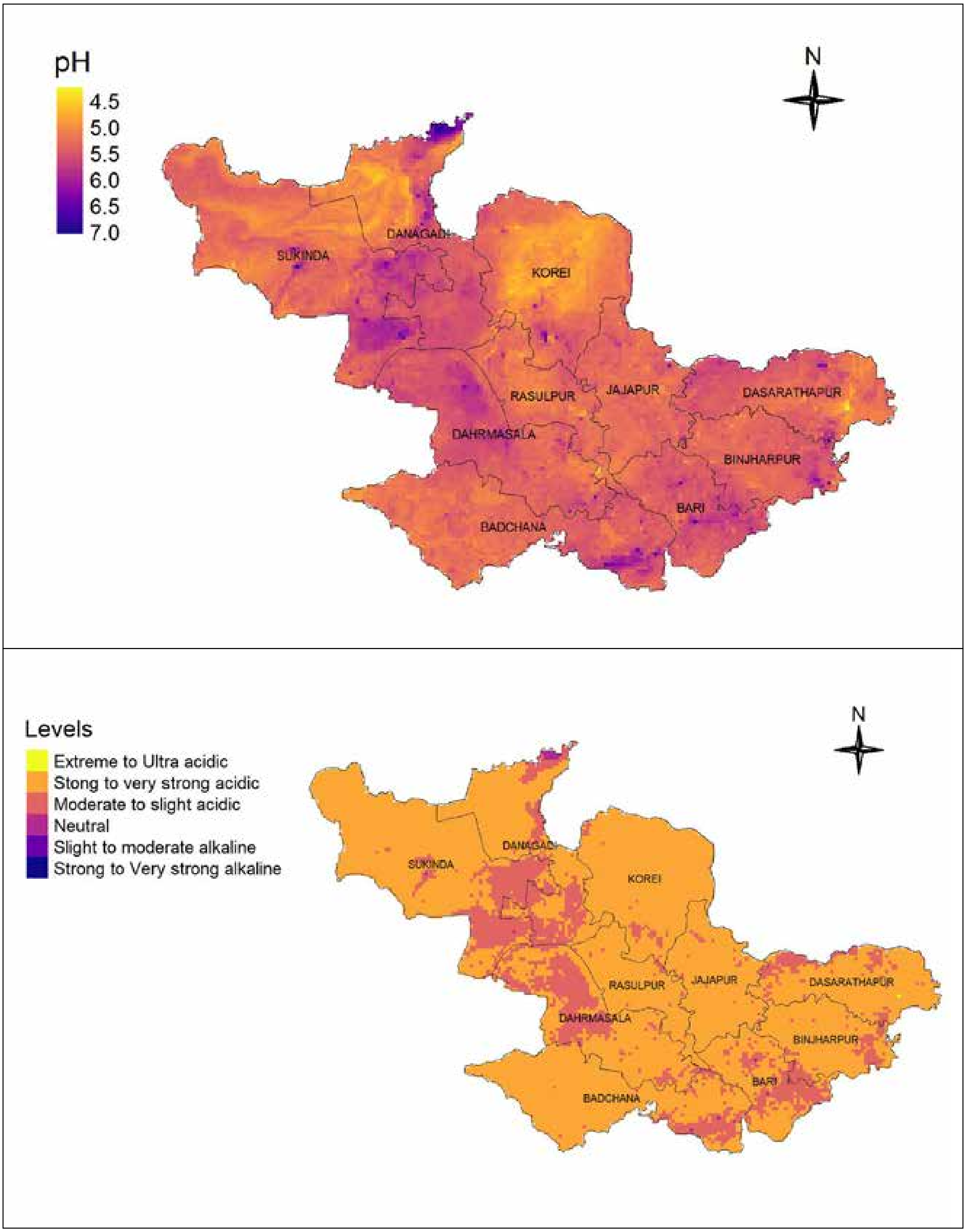


Figure 5.122. pH status in soils of Jajpur district.

Electrical conductivity

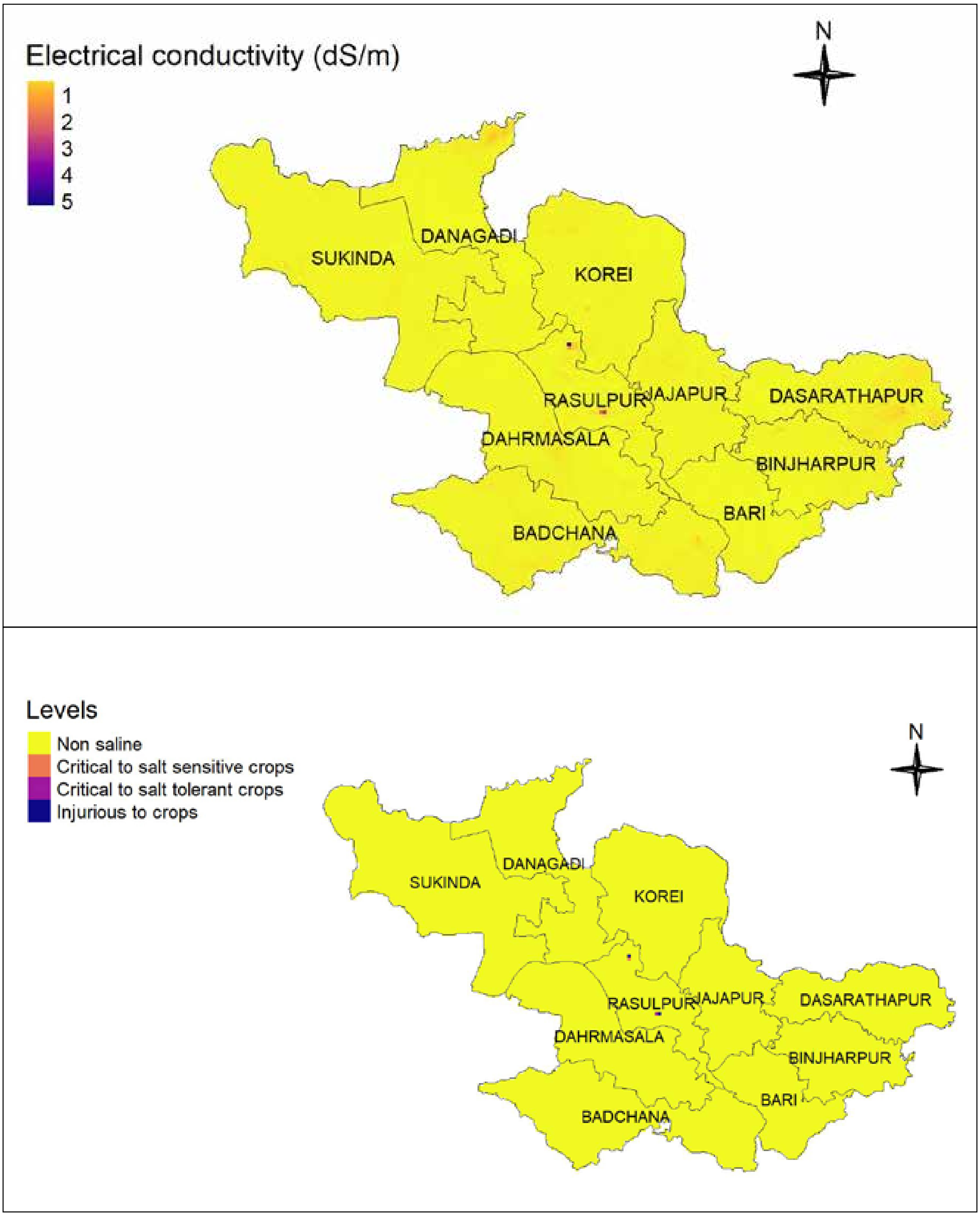


Figure 5.123. Status of electrical conductivity in soils of Jajpur district.

Organic carbon

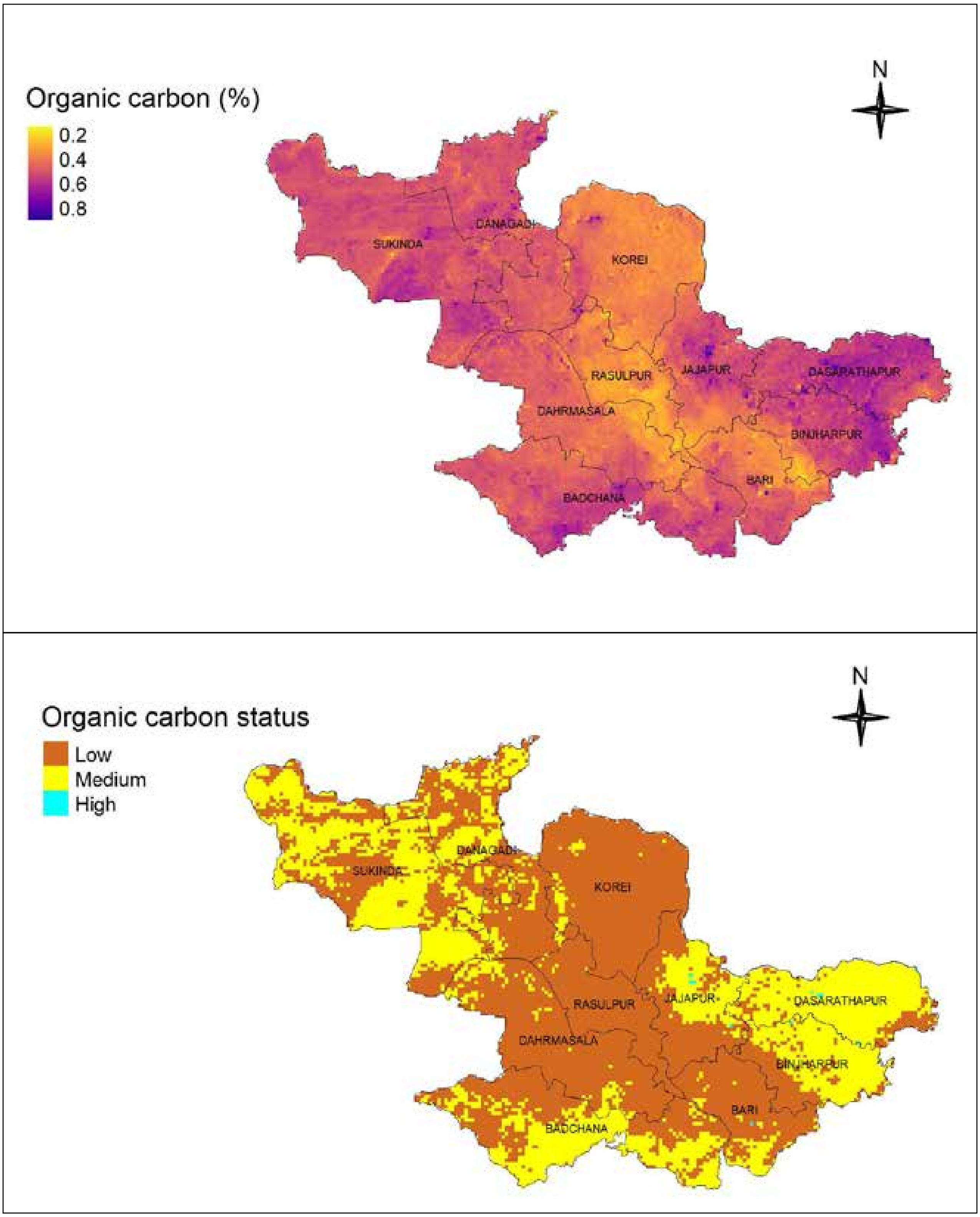


Figure 5.124. Organic carbon status in soils of Jajpur district.

Available Phosphorous

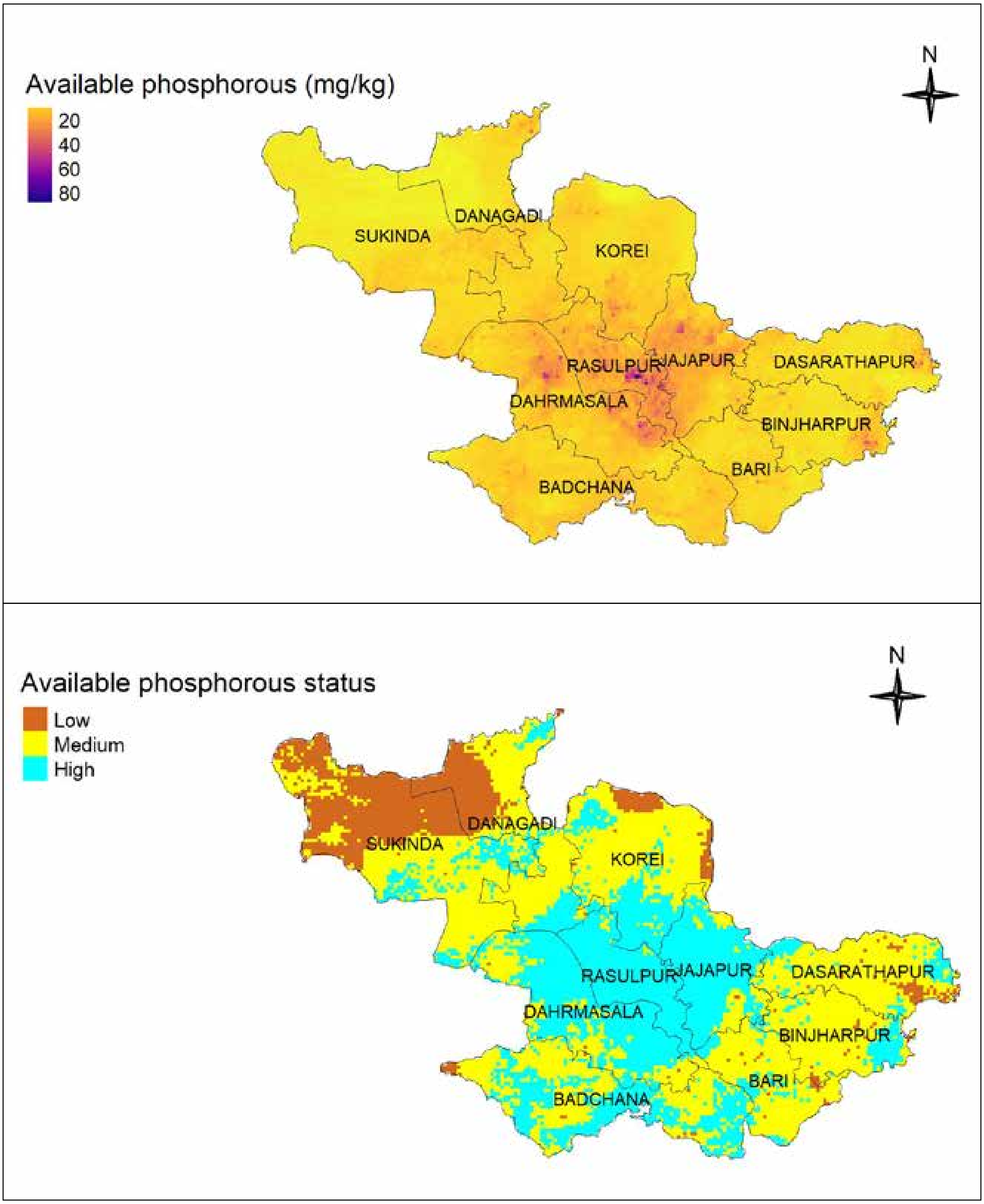


Figure 5.125. Status of available phosphorous in soils of Jajpur district.

Exchangeable Potassium

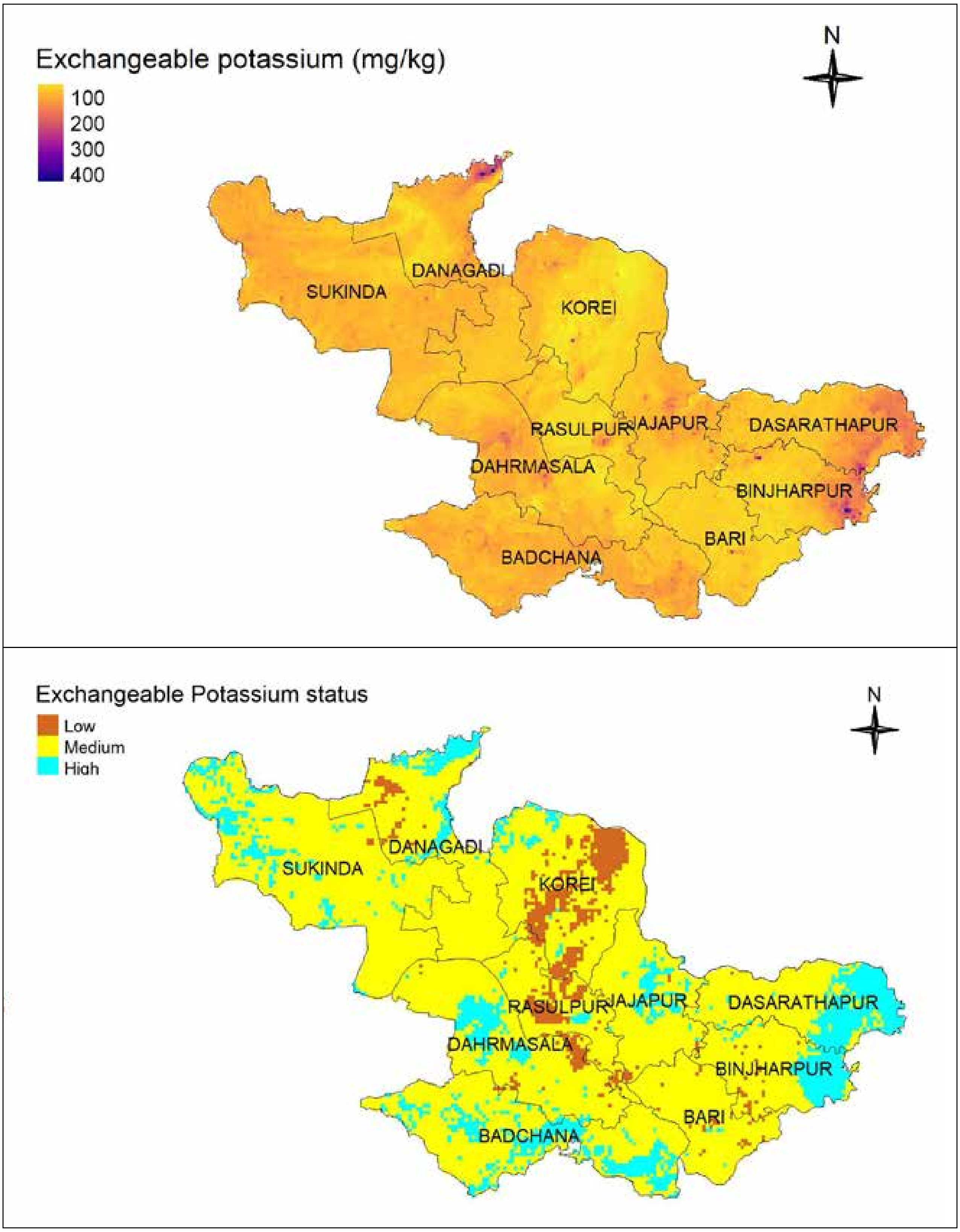


Figure 5.126. Status of exchangeable potassium in soils of Jajpur district.

Available Sulfur

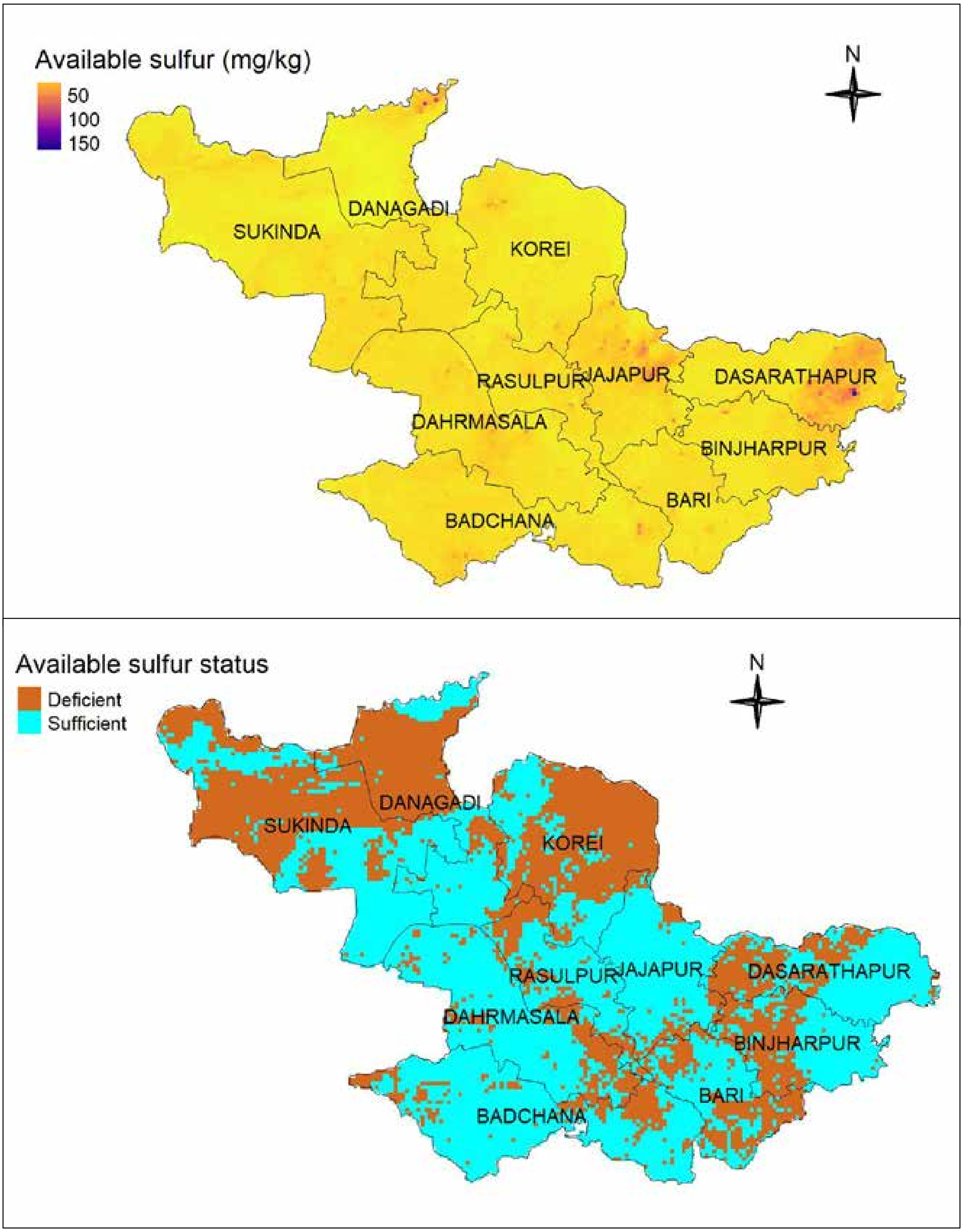


Figure 5.127. Status of available sulfur in soils of Jajpur district.

Available Boron

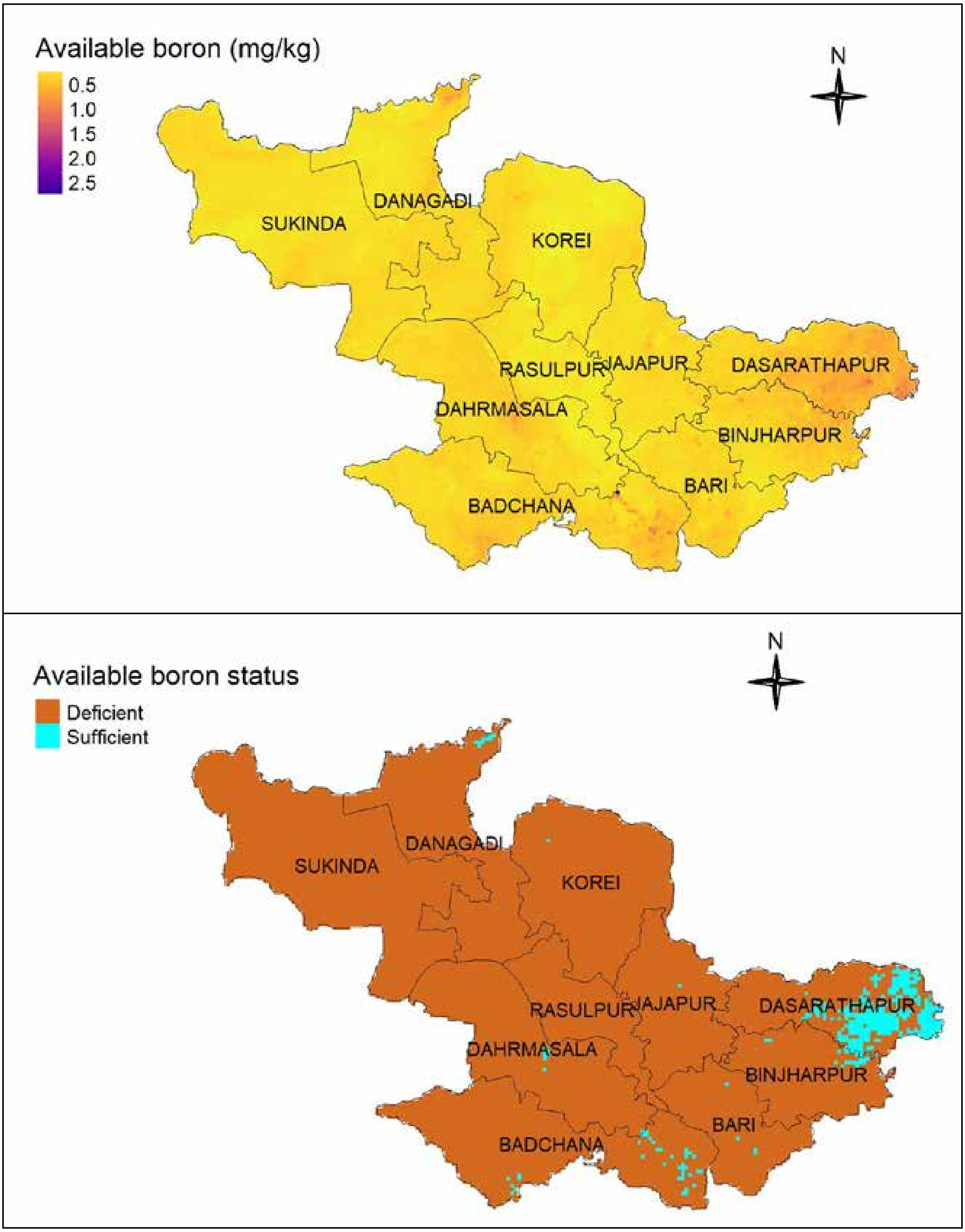


Figure 5.128. Status of available boron in soils of Jajpur district.

Available Zinc

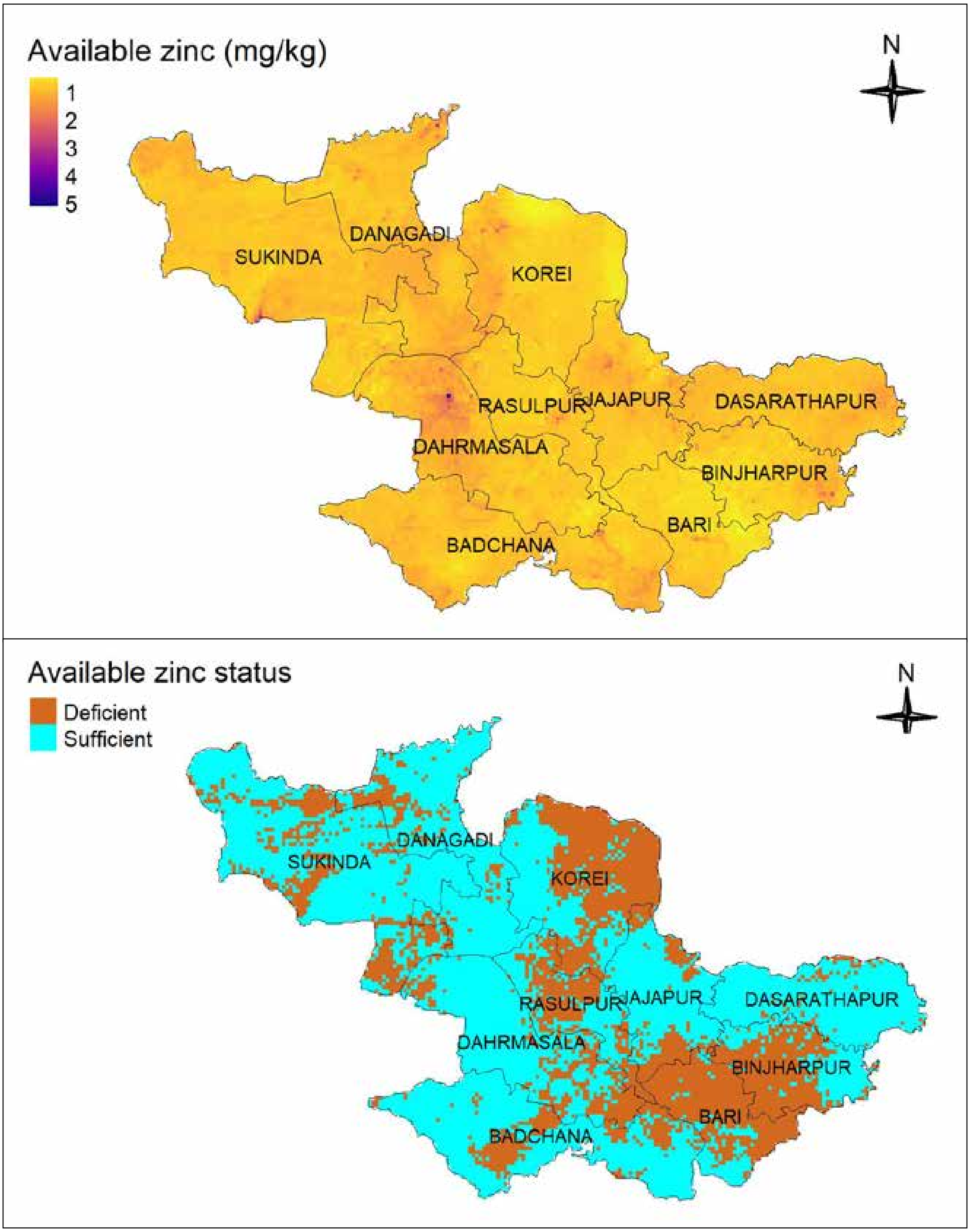


Figure 5.129. Status of available zinc in soils of Jajpur district.

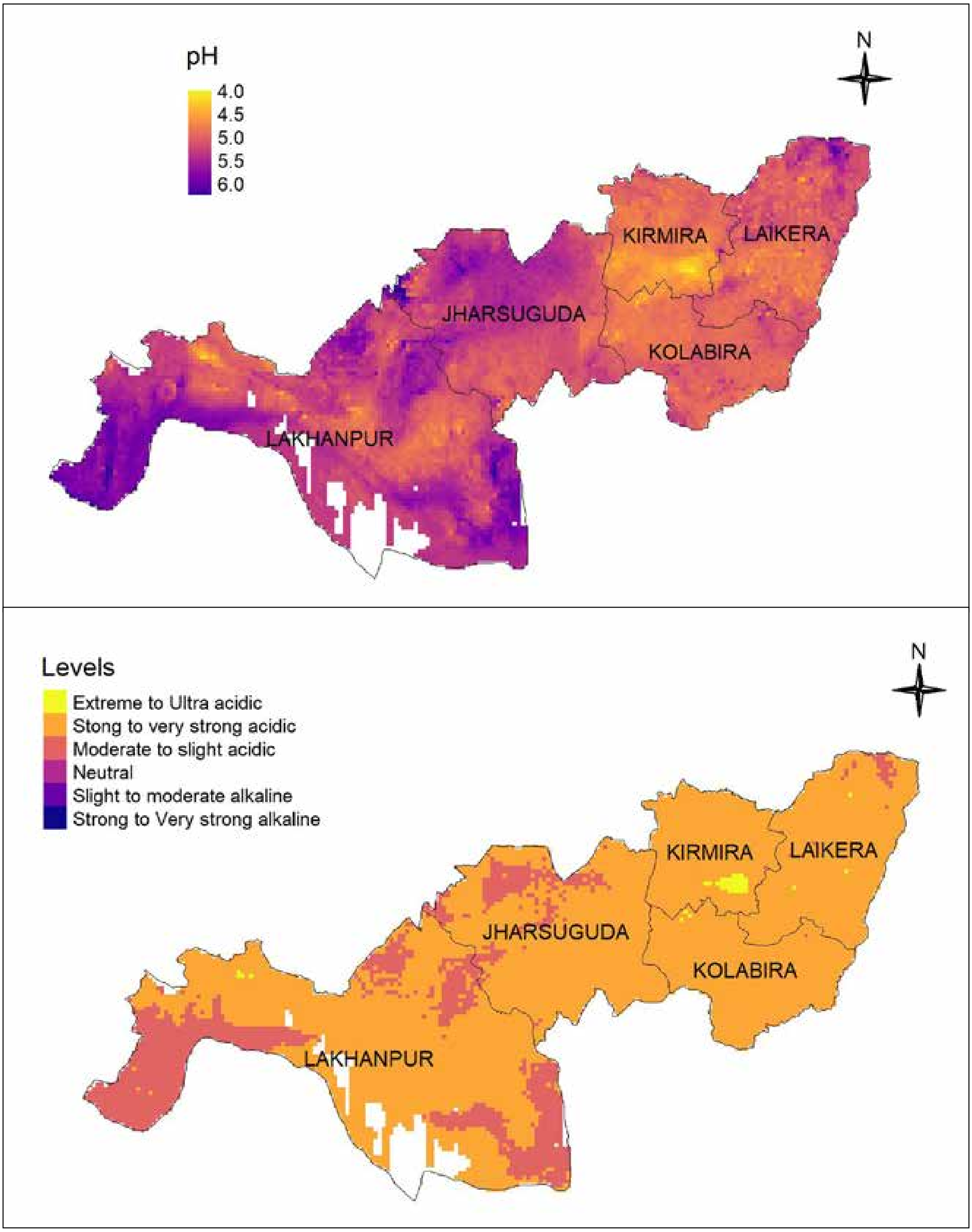


Figure 5.130. pH status in soils of Jharsuguda district.

Electrical conductivity

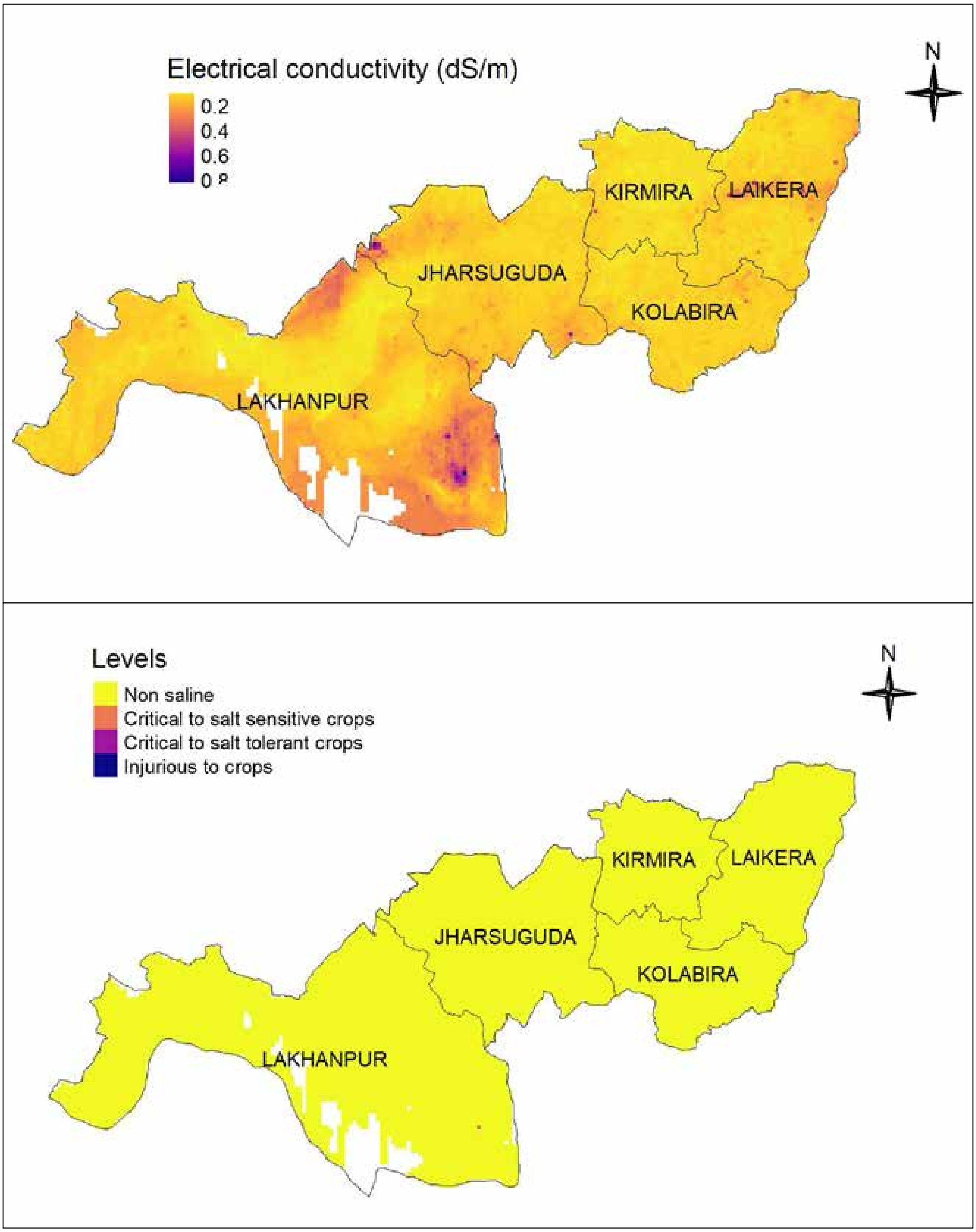


Figure 5.131. Status of electrical conductivity in soils of Jharsuguda district.

Organic carbon

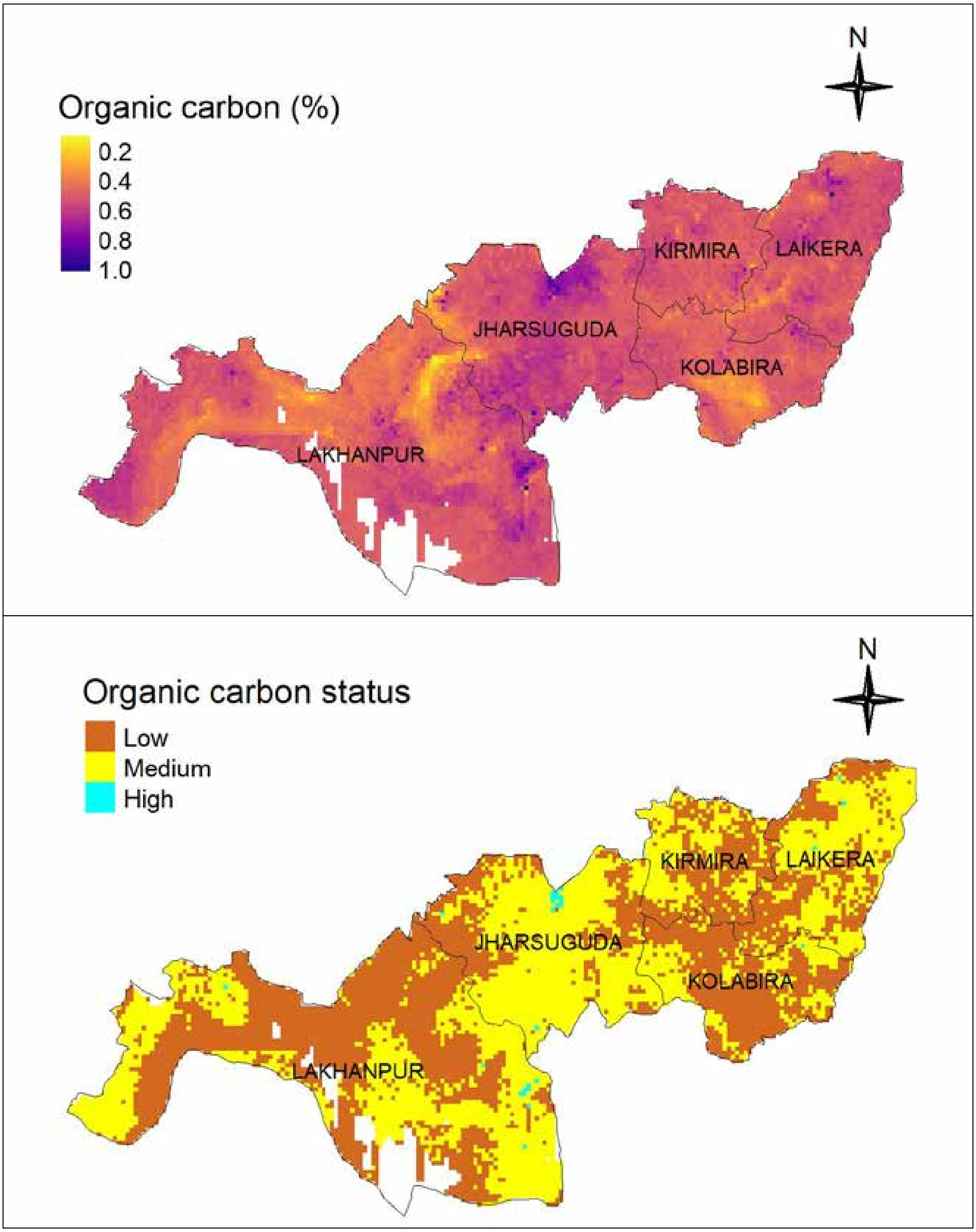


Figure 5.132. Organic carbon status in soils of Jharsuguda district.

Available Phosphorous

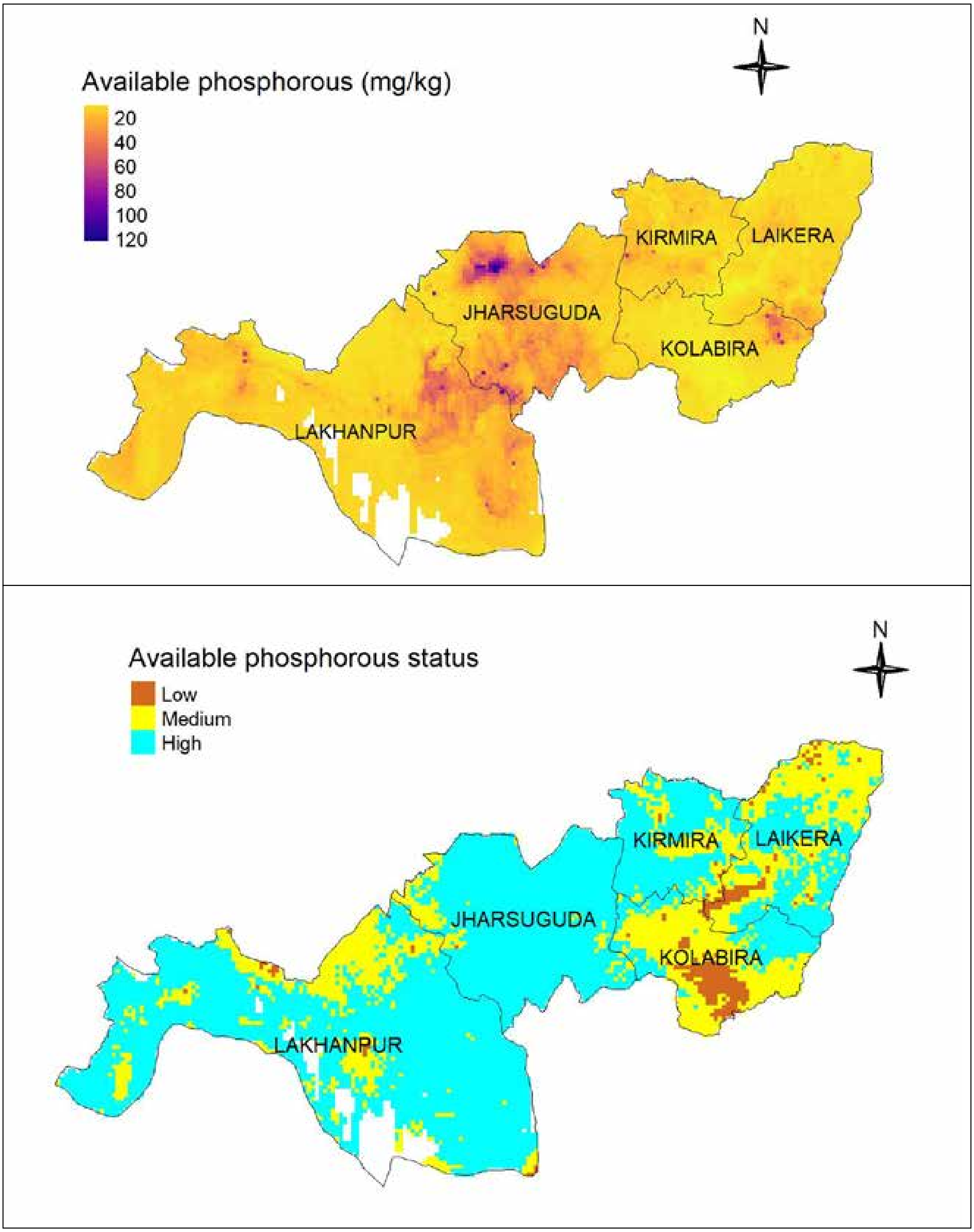


Figure 5.133. Status of available phosphorous in soils of Jharsuguda district.

Exchangeable Potassium

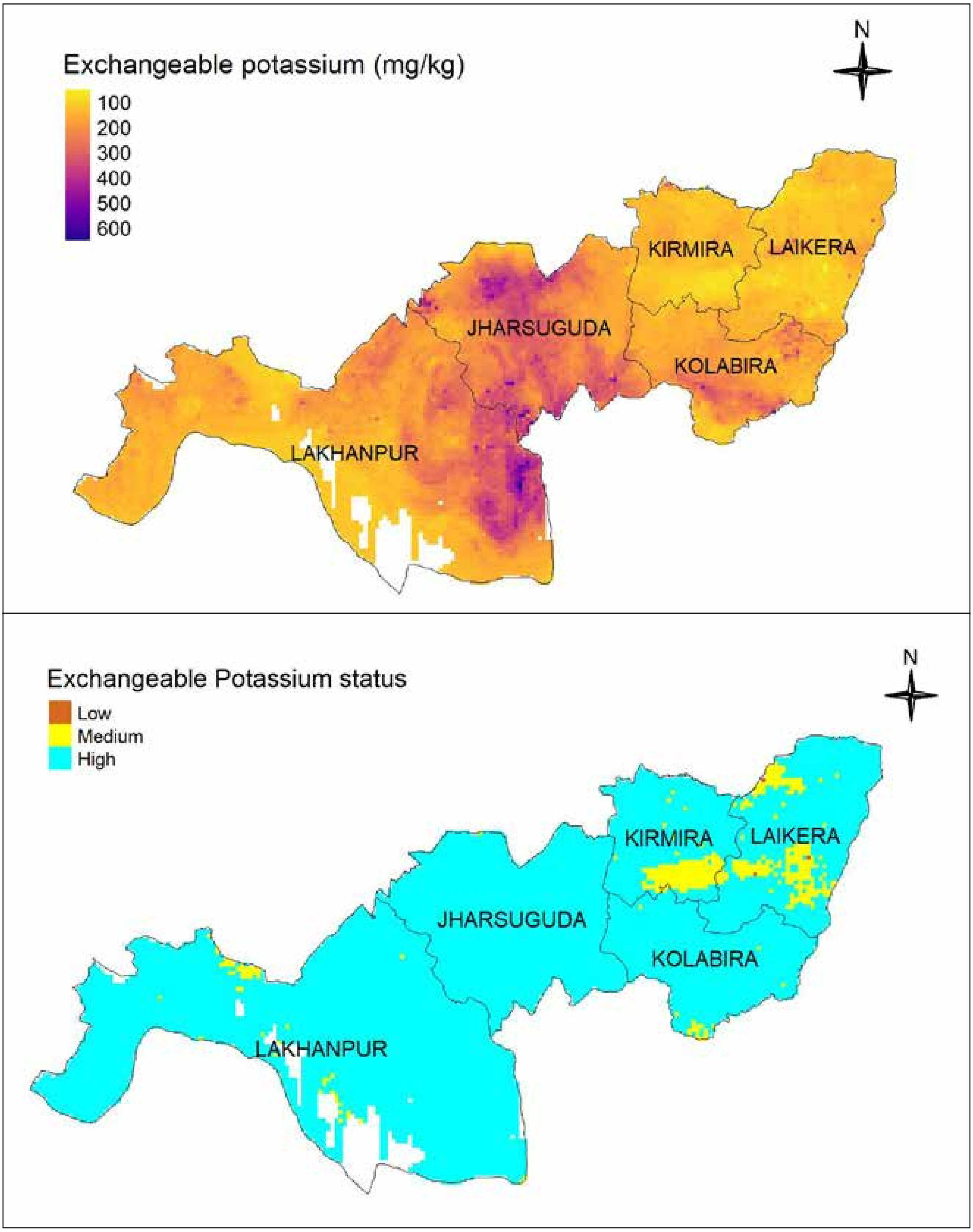


Figure 5.134. Status of exchangeable potassium in soils of Jharsuguda district.

Available Sulfur

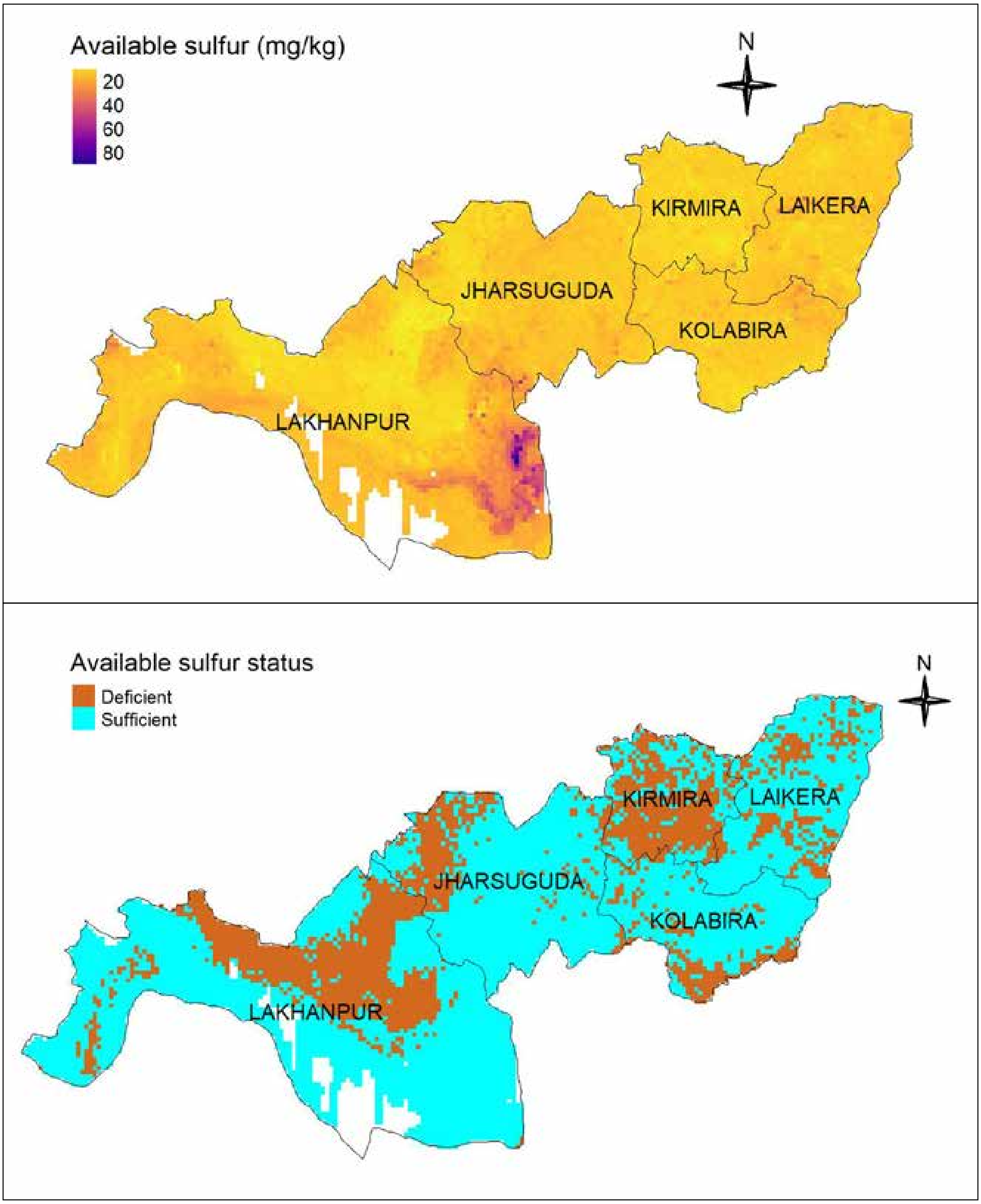


Figure 5.135. Status of available sulfur in soils of Jharsuguda district.

Available Boron

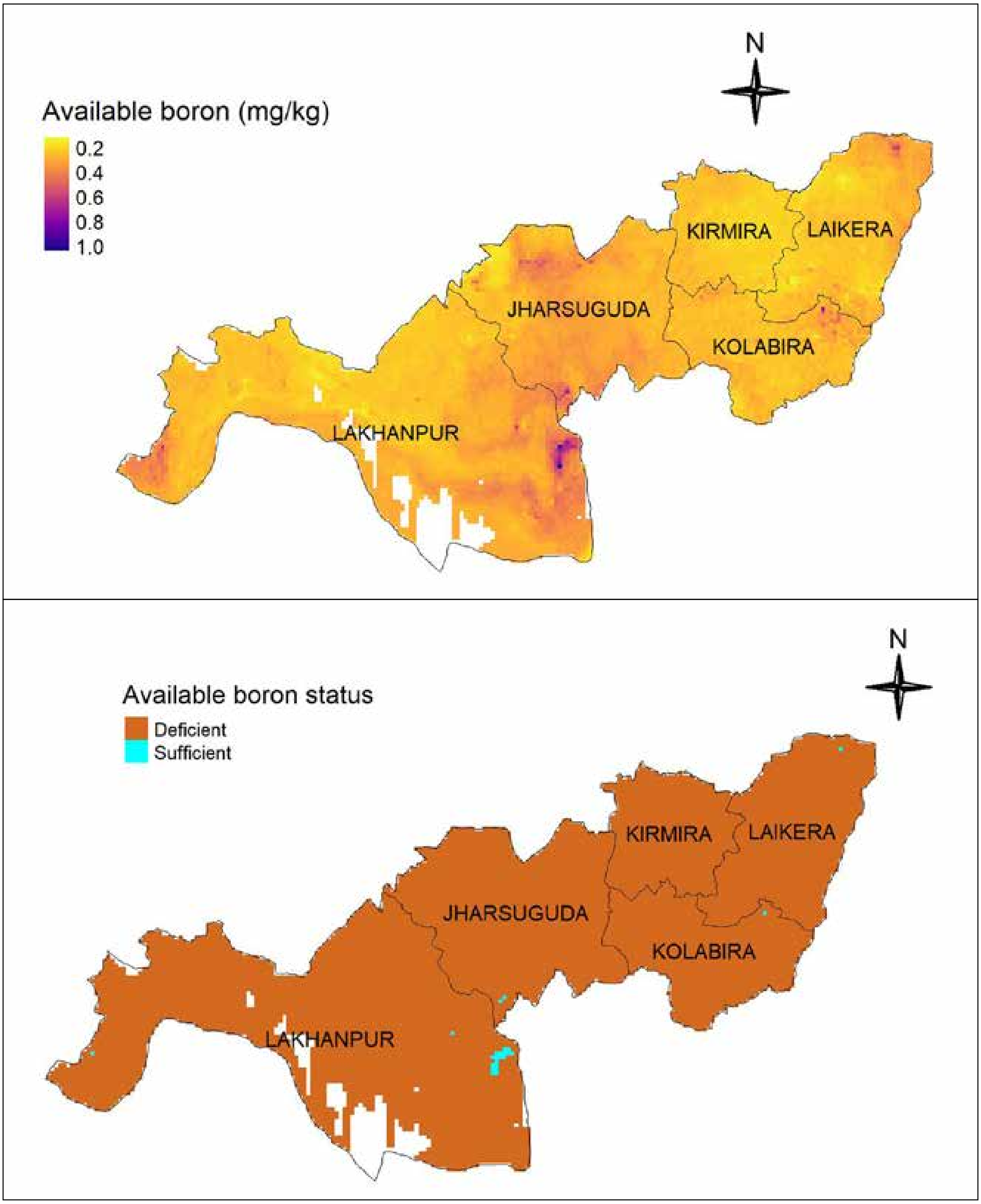


Figure 5.136. Status of available boron in soils of Jharsuguda district.

Available Zinc

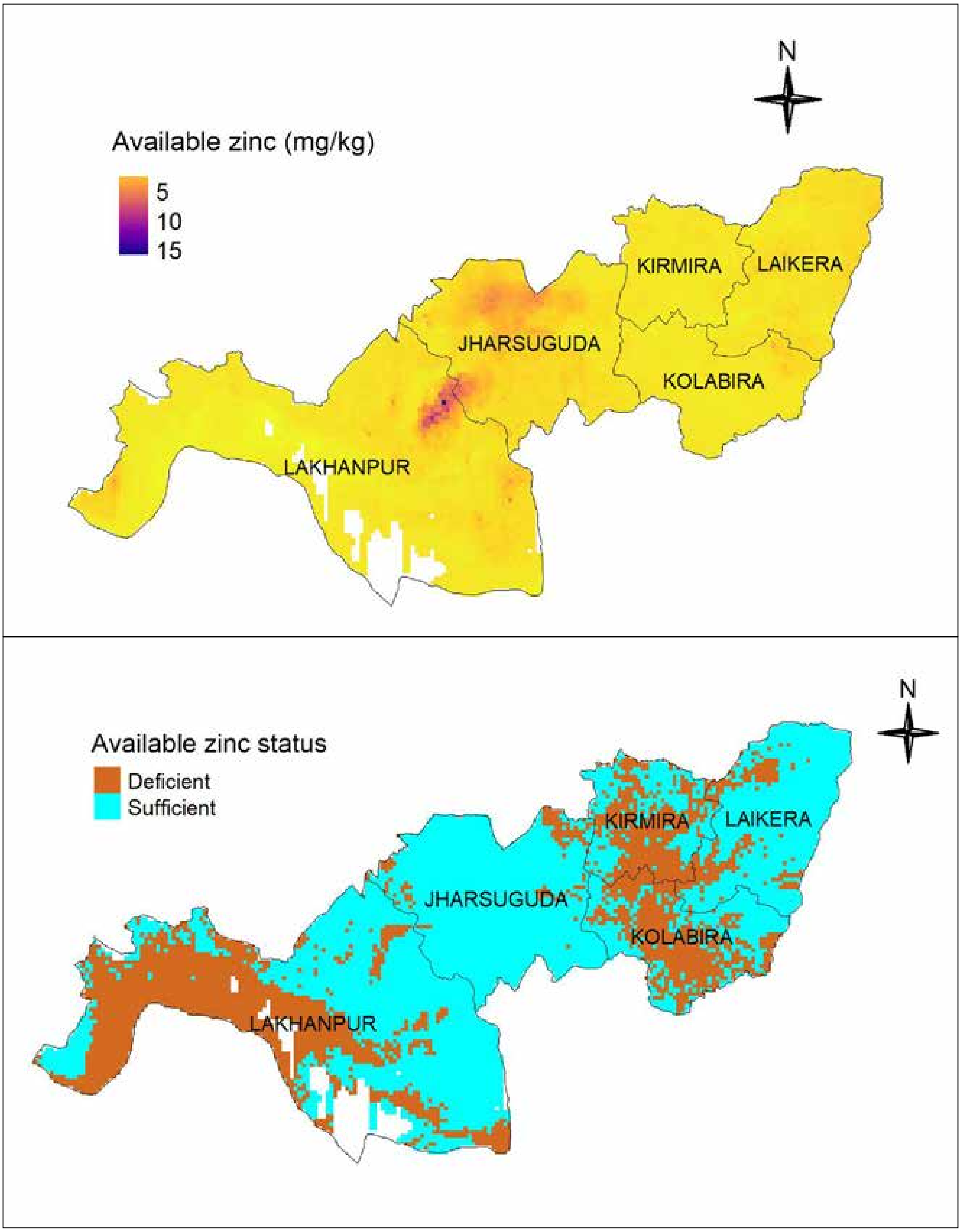


Figure 5.137. Status of available zinc in soils of Jharsuguda district.

Kalahandi | pH

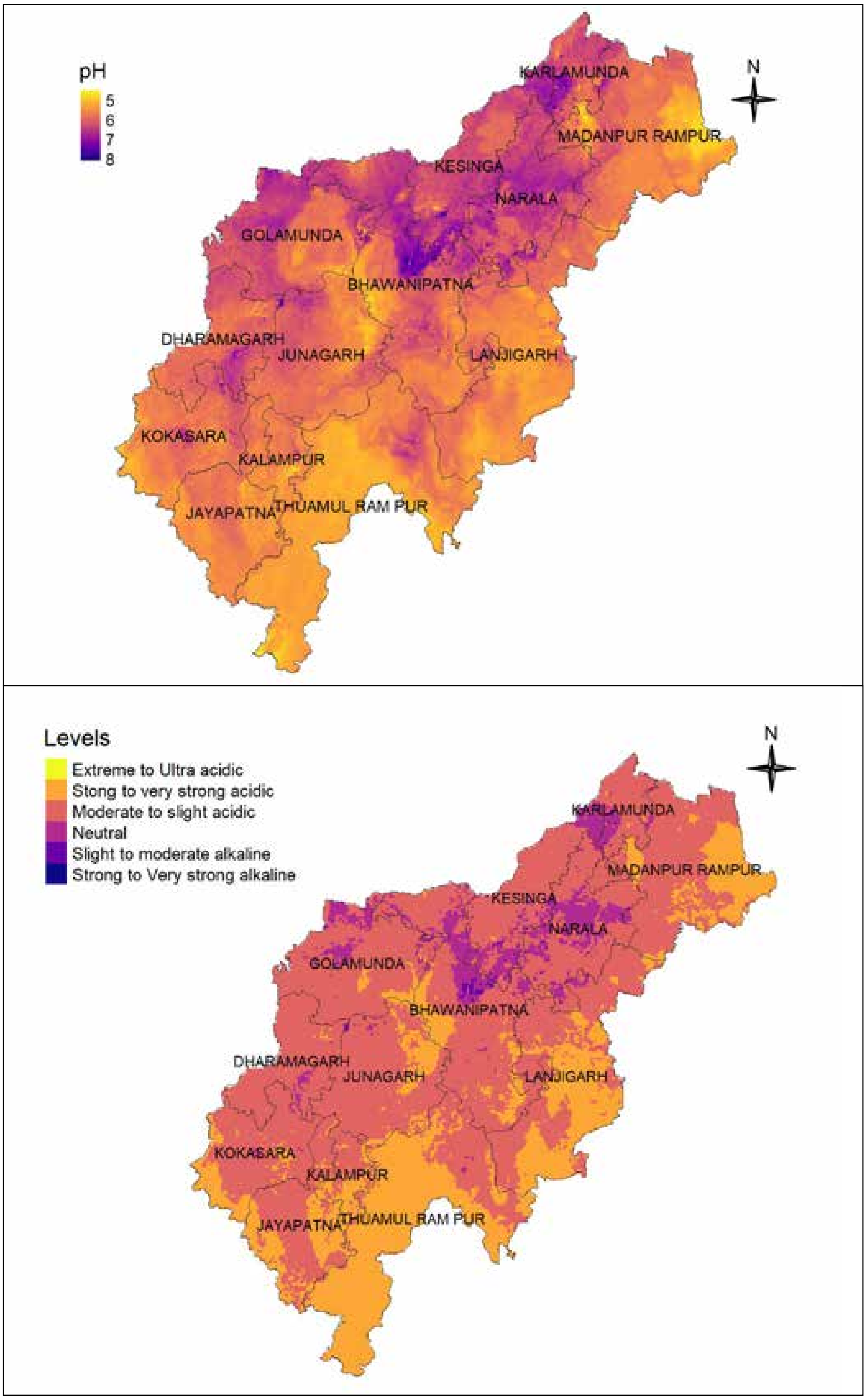


Figure 5.138. pH status in soils of Kalahandi district.

Electrical conductivity

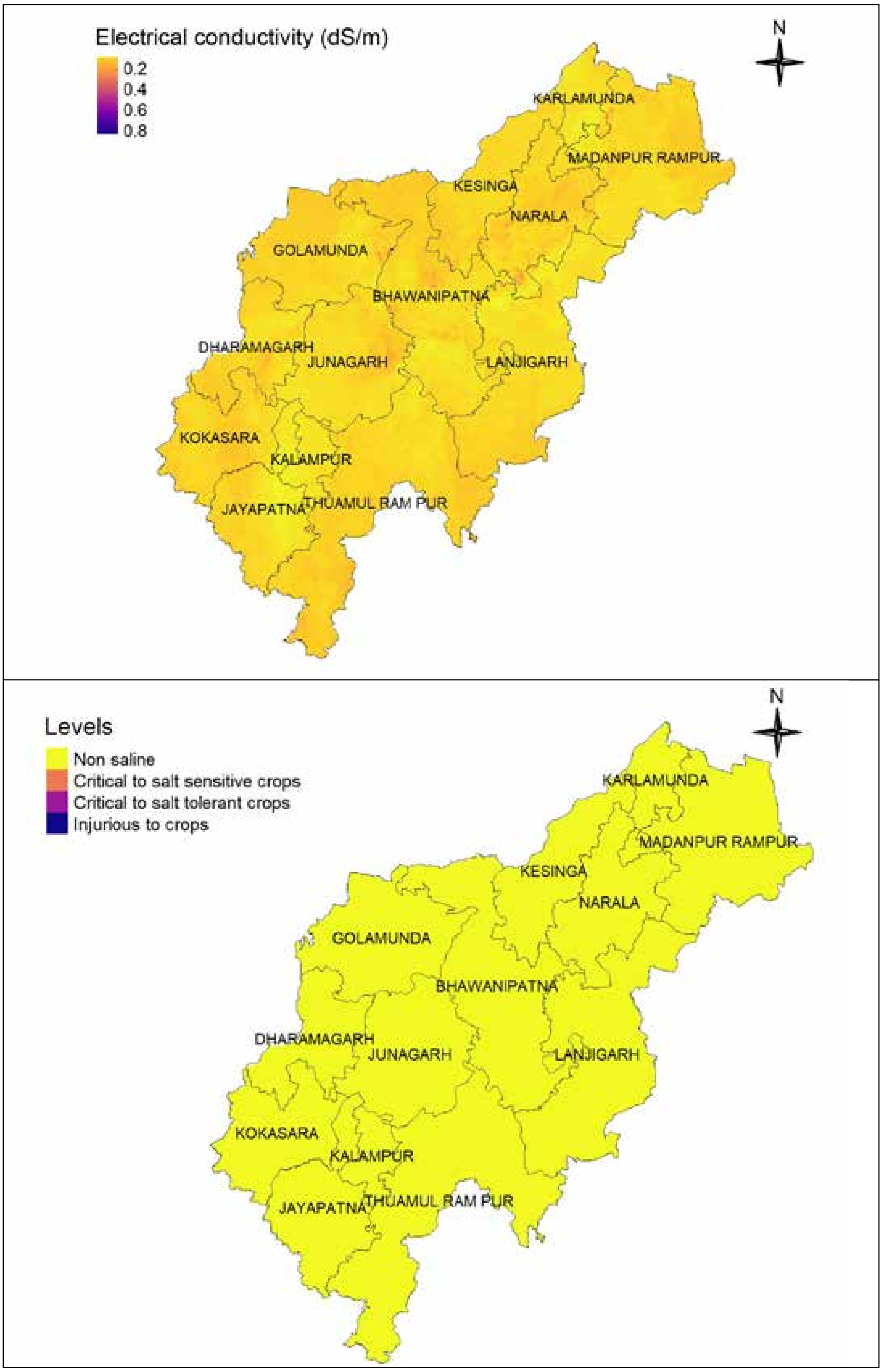


Figure 5.139. Status of electrical conductivity in soils of Kalahandi district.

Organic carbon

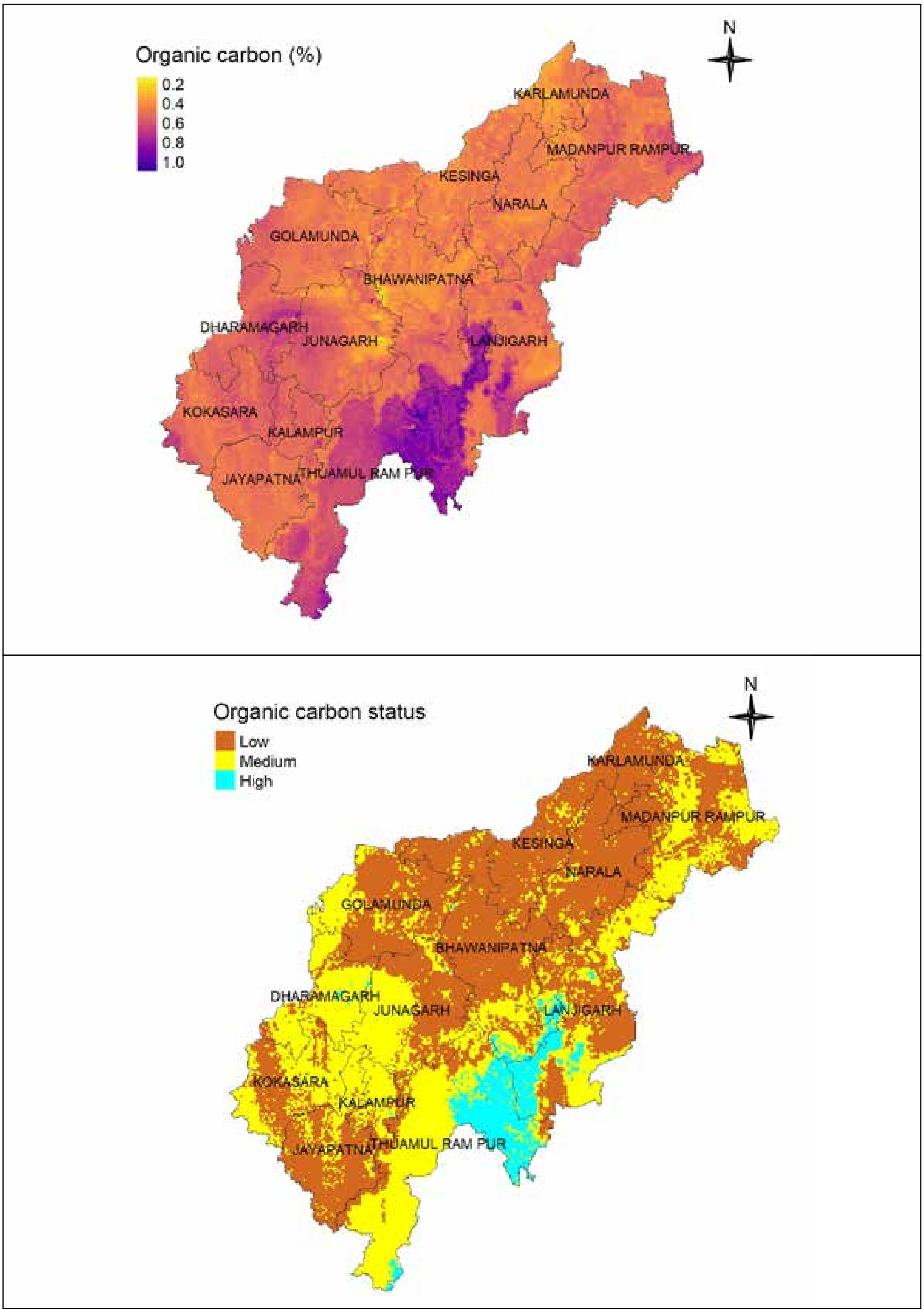


Figure 5.140. Organic carbon status in soils of Kalahandi district.

Available Phosphorous

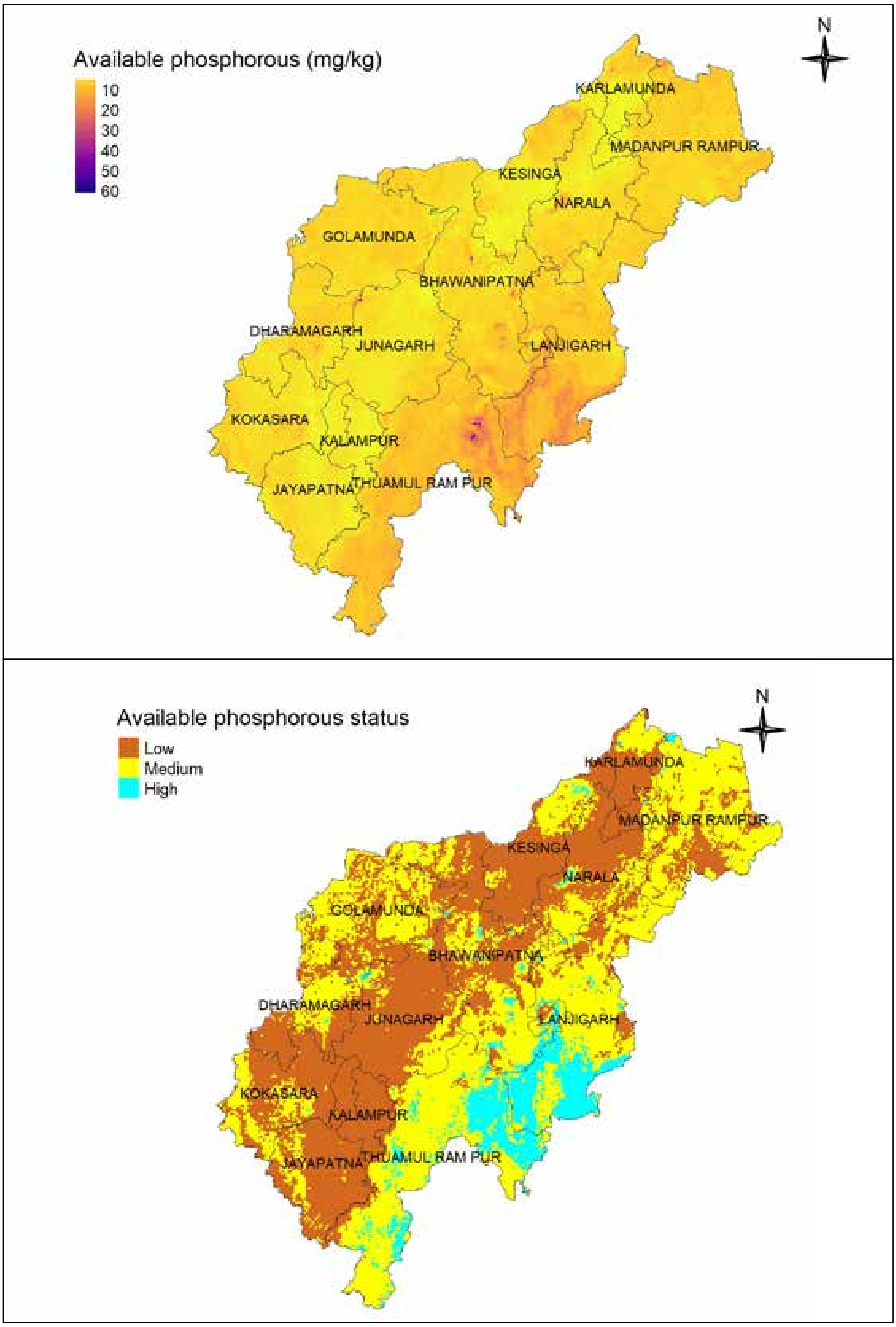


Figure 5.141. Status of available phosphorous in soils of Kalahandi district.

Exchangeable Potassium

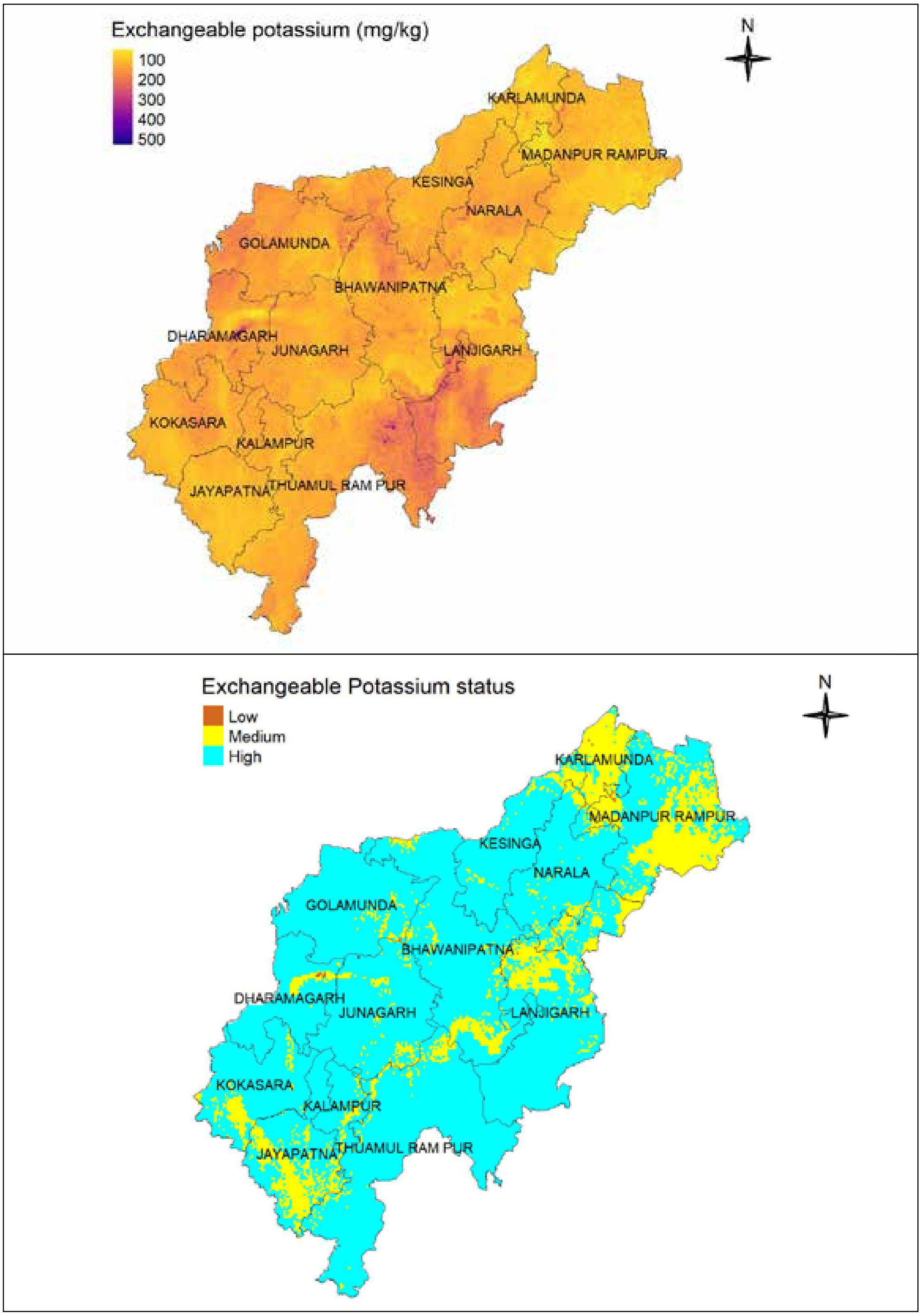


Figure 5.142. Status of exchangeable potassium in soils of Kalahandi district.

Available Sulfur

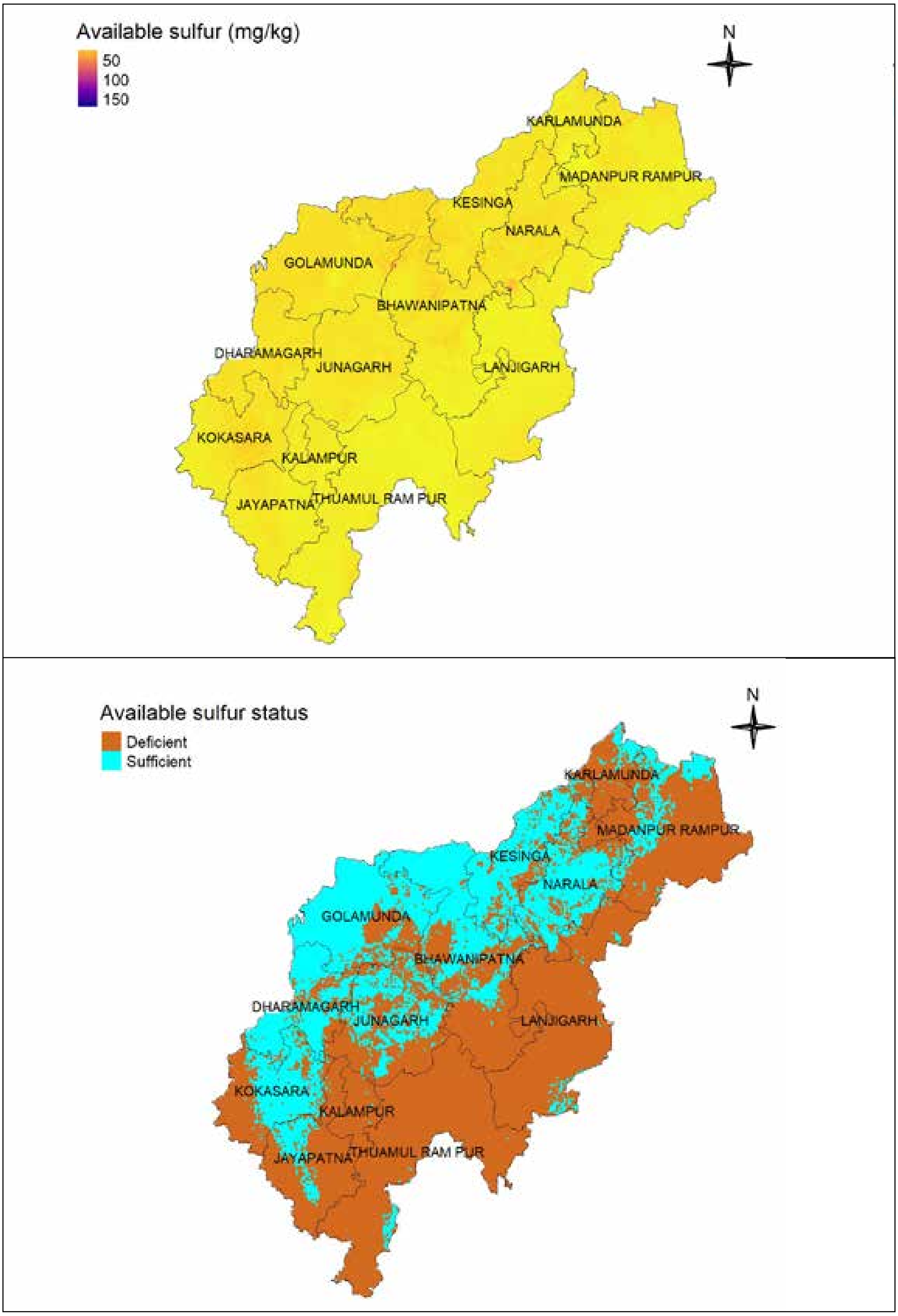


Figure 5.143. Status of available sulfur in soils of Kalahandi district.

Available Boron

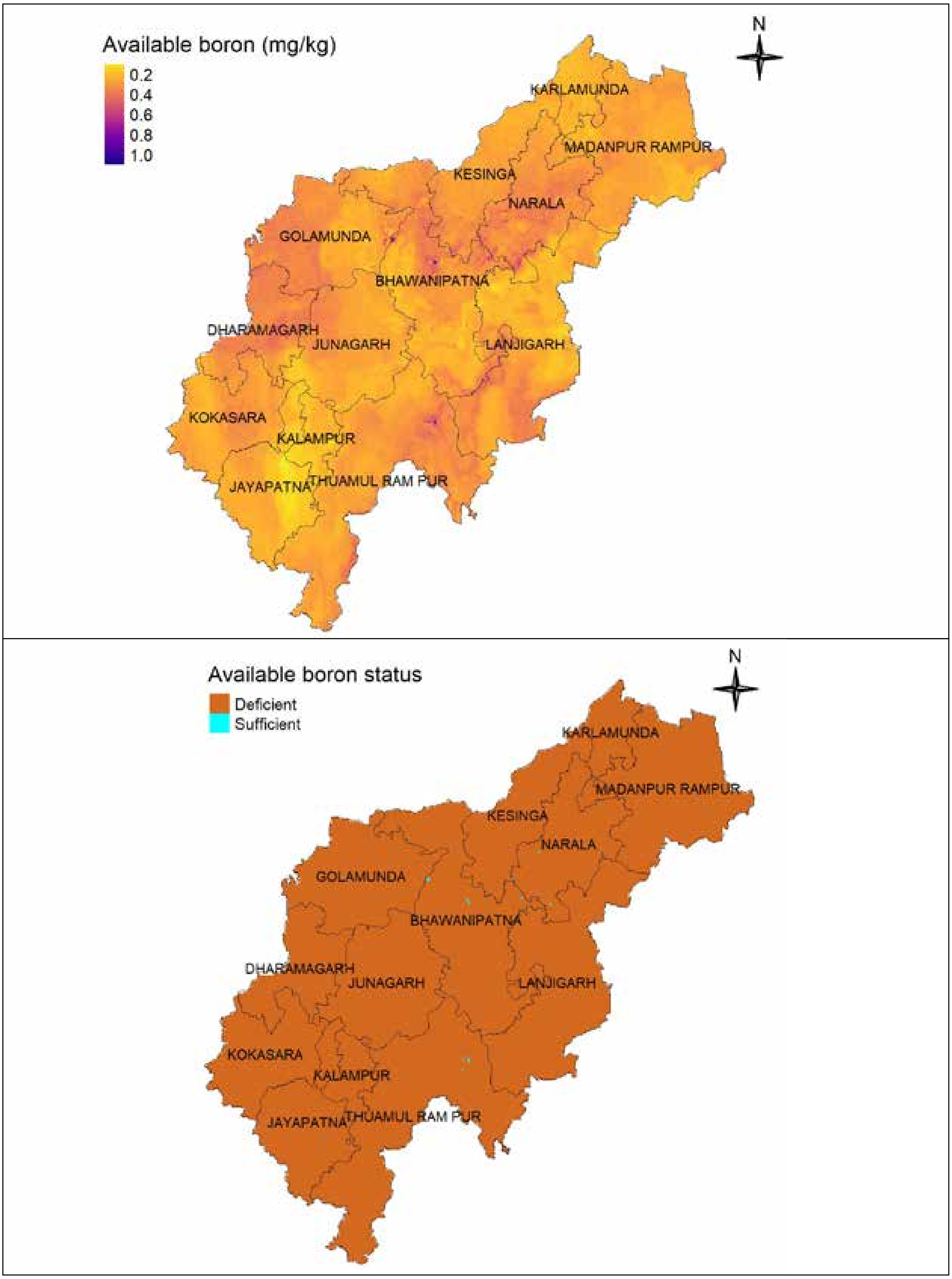


Figure 5.144. Status of available boron in soils of Kalahandi district.

Available Zinc

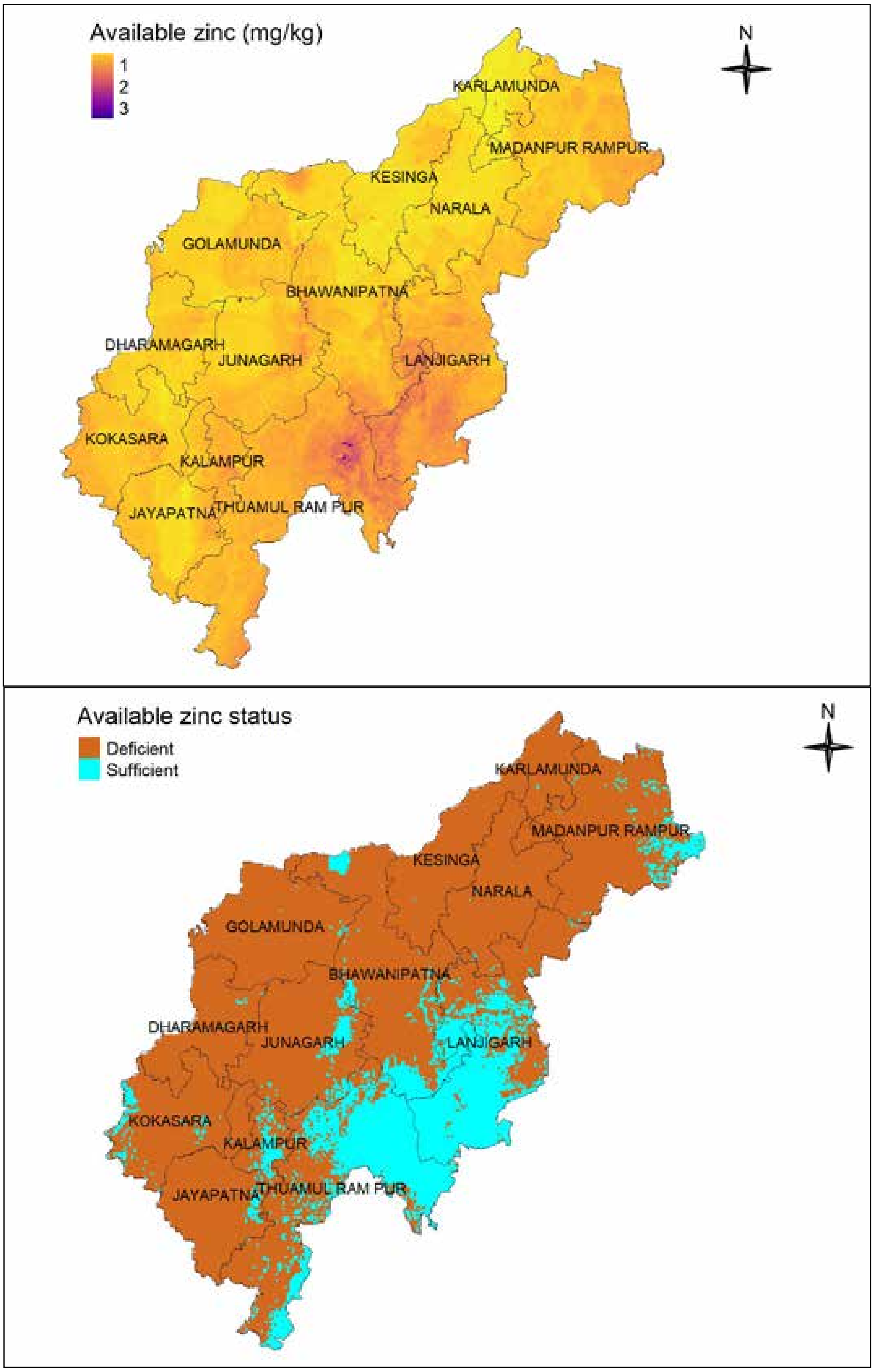


Figure 5.145. Status of available zinc in soils of Kalahandi district.

Kandhamal | pH

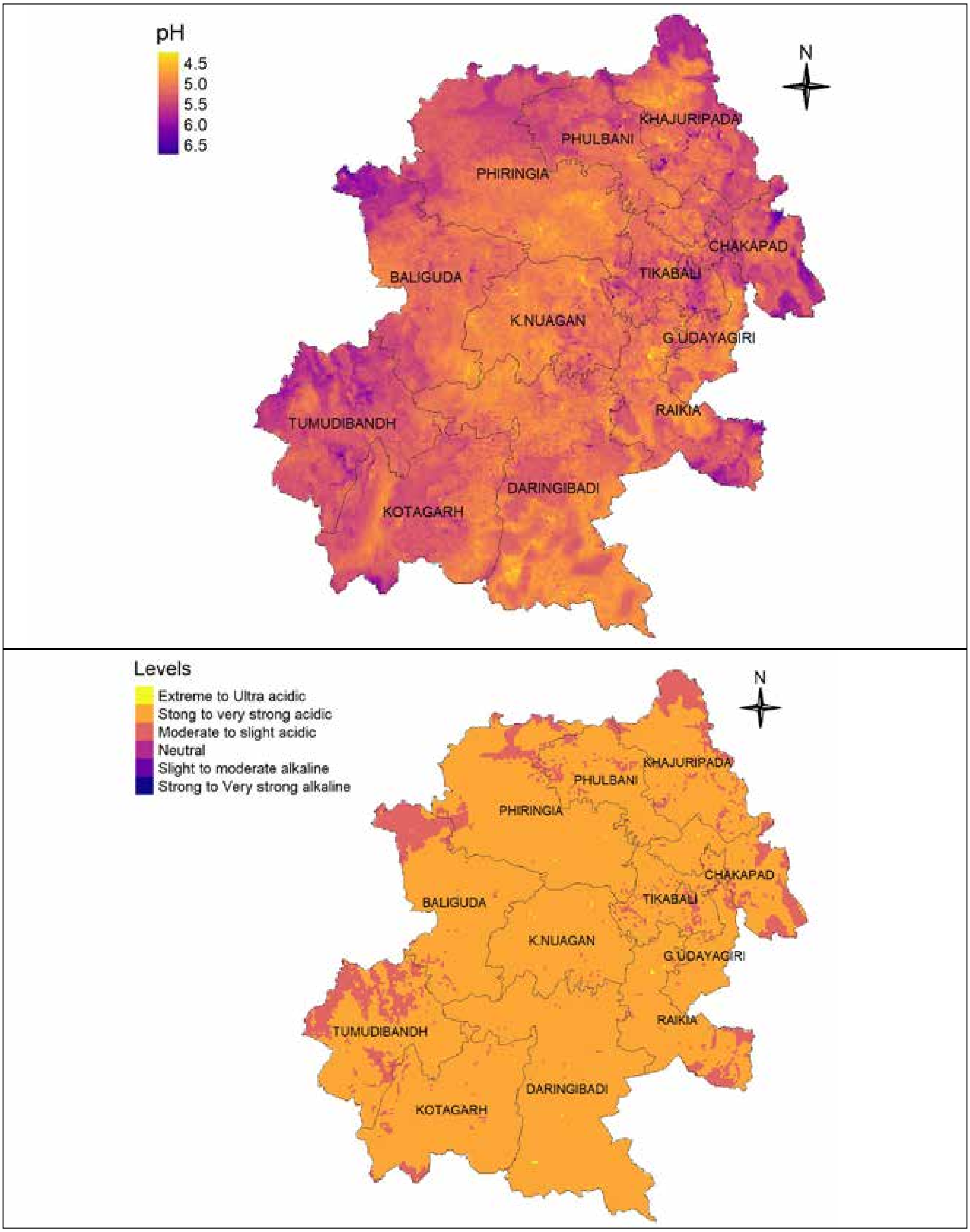


Figure 5.146. pH status in soils of Kandhamal district.

Electrical conductivity

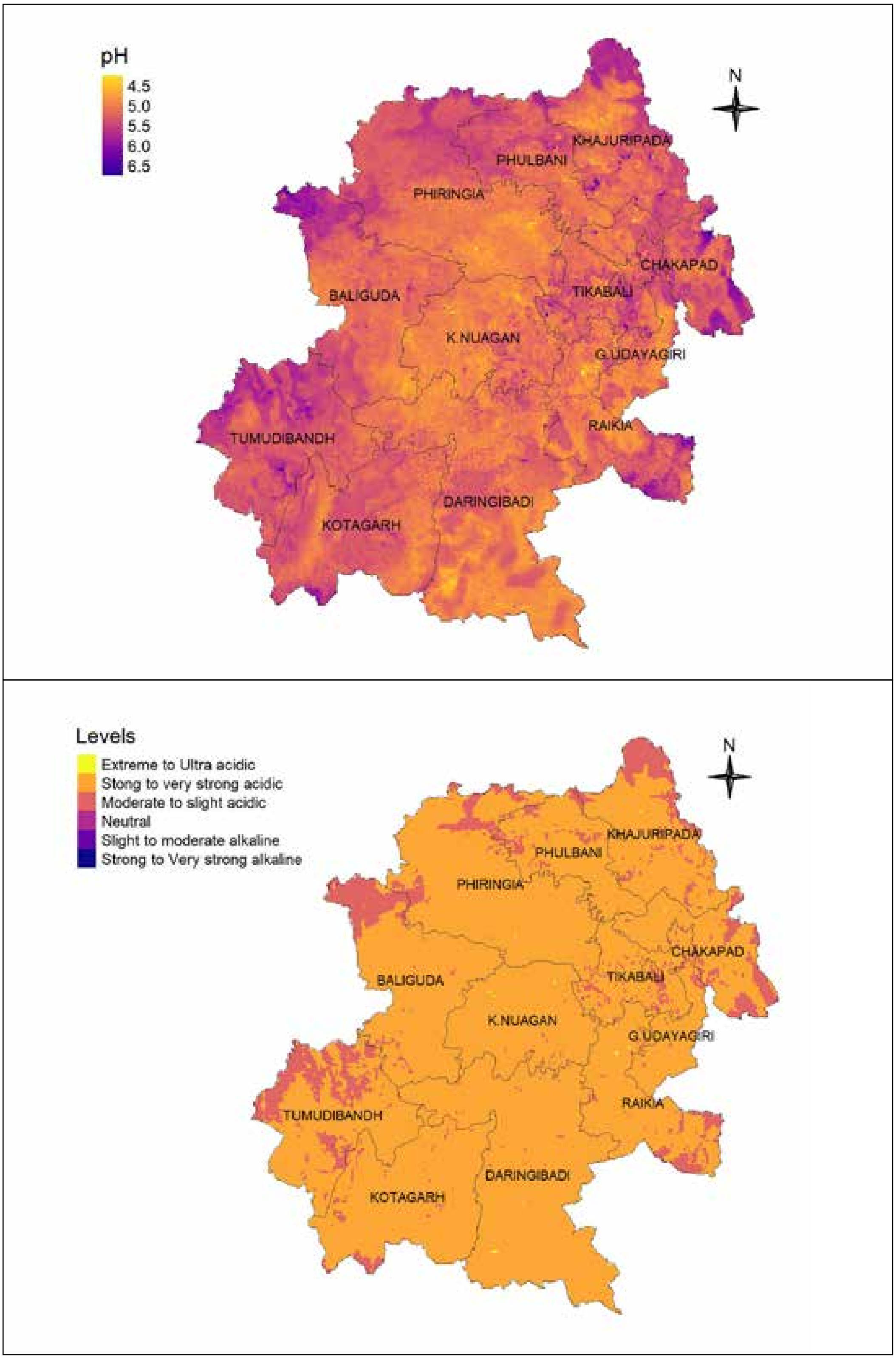


Figure 5.147. Status of electrical conductivity in soils of Kandhamal district.

Organic carbon

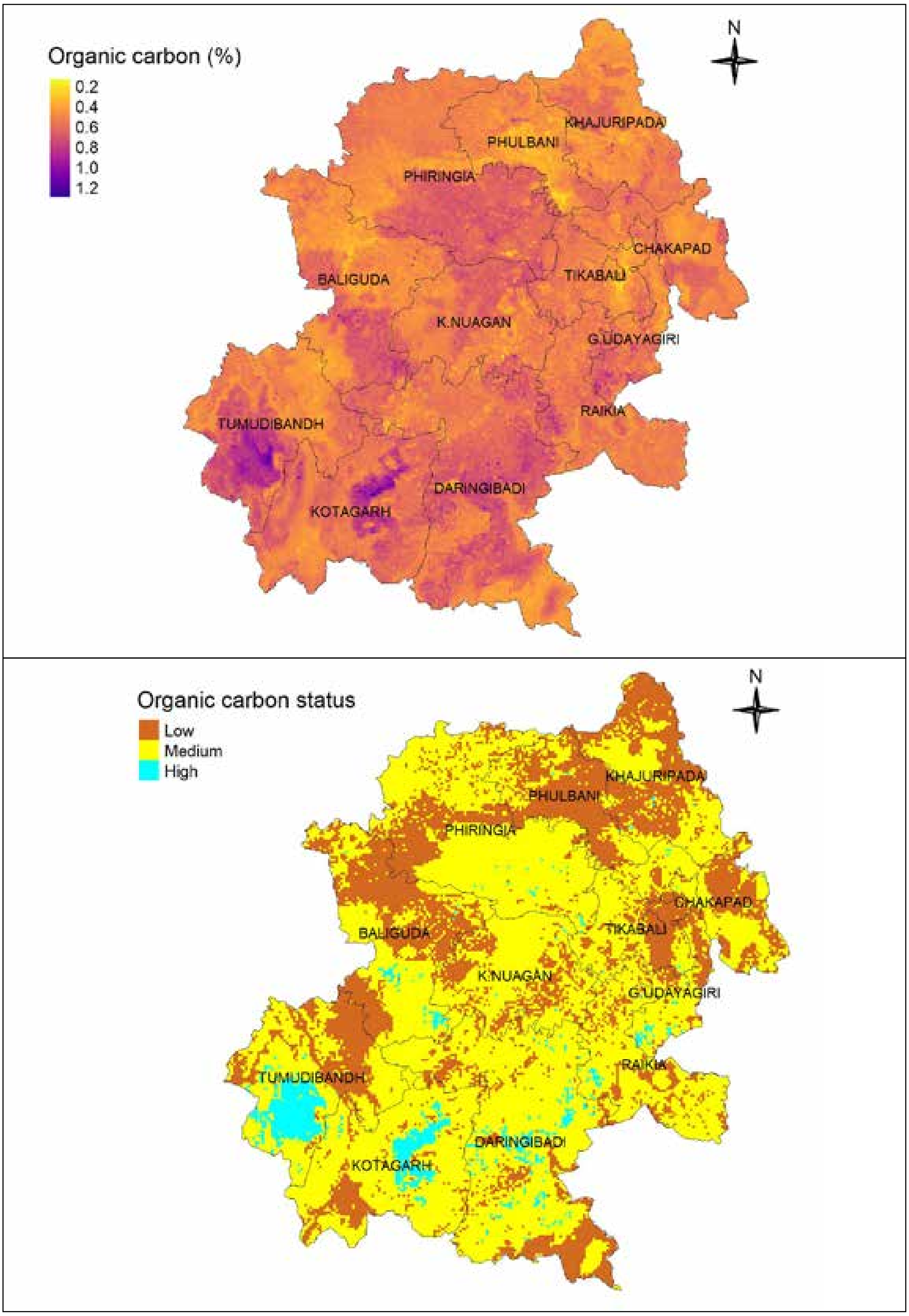


Figure 5.148. Status of organic carbon in soils of Kandhamal district.

Available Phosphorous

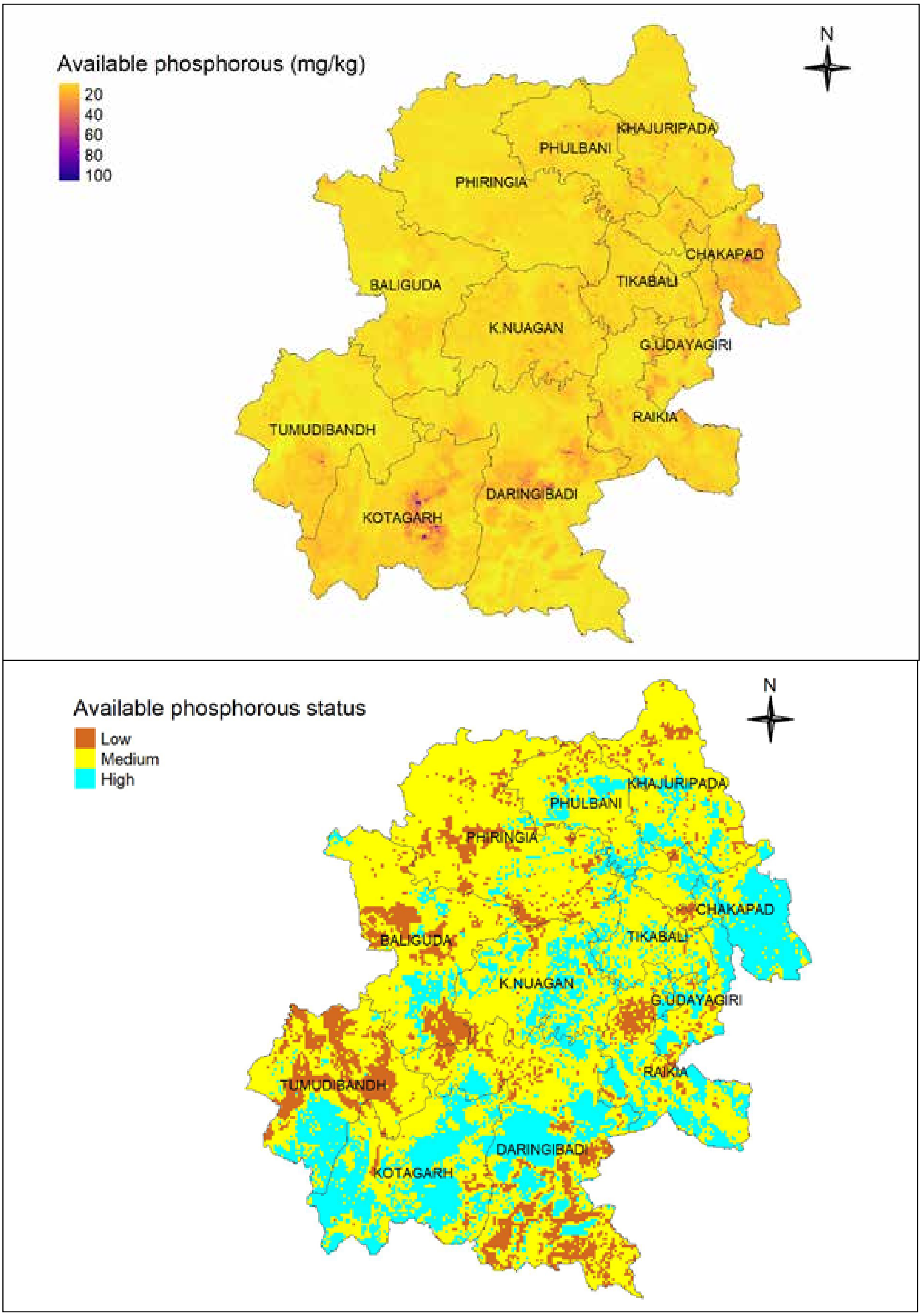


Figure 5.149. Status of available phosphorous in soils of Kandhamal district.

Exchangeable Potassium

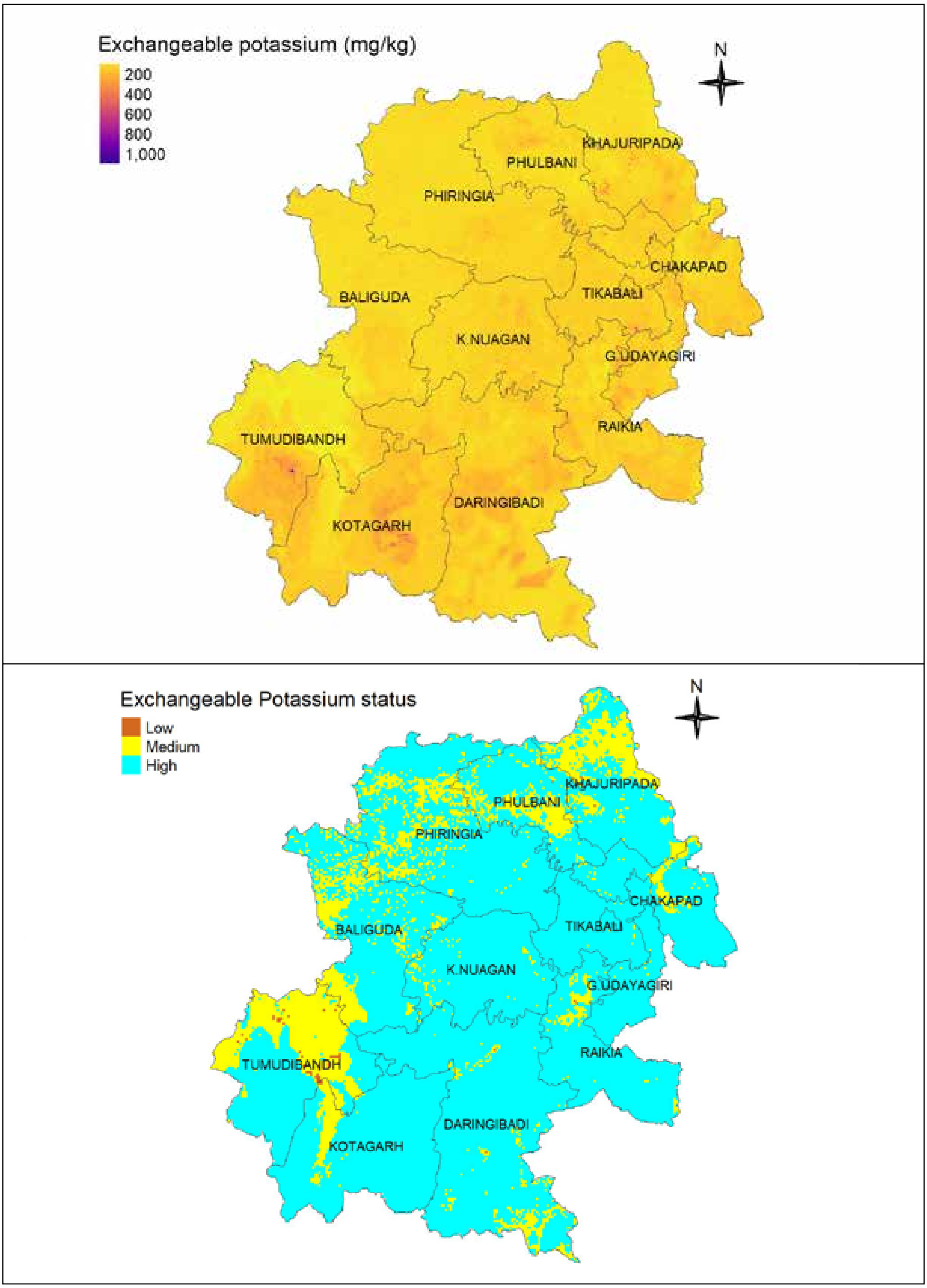


Figure 5.150. Status of exchangeable potassium in soils of Kandhamal district.

Available Sulfur

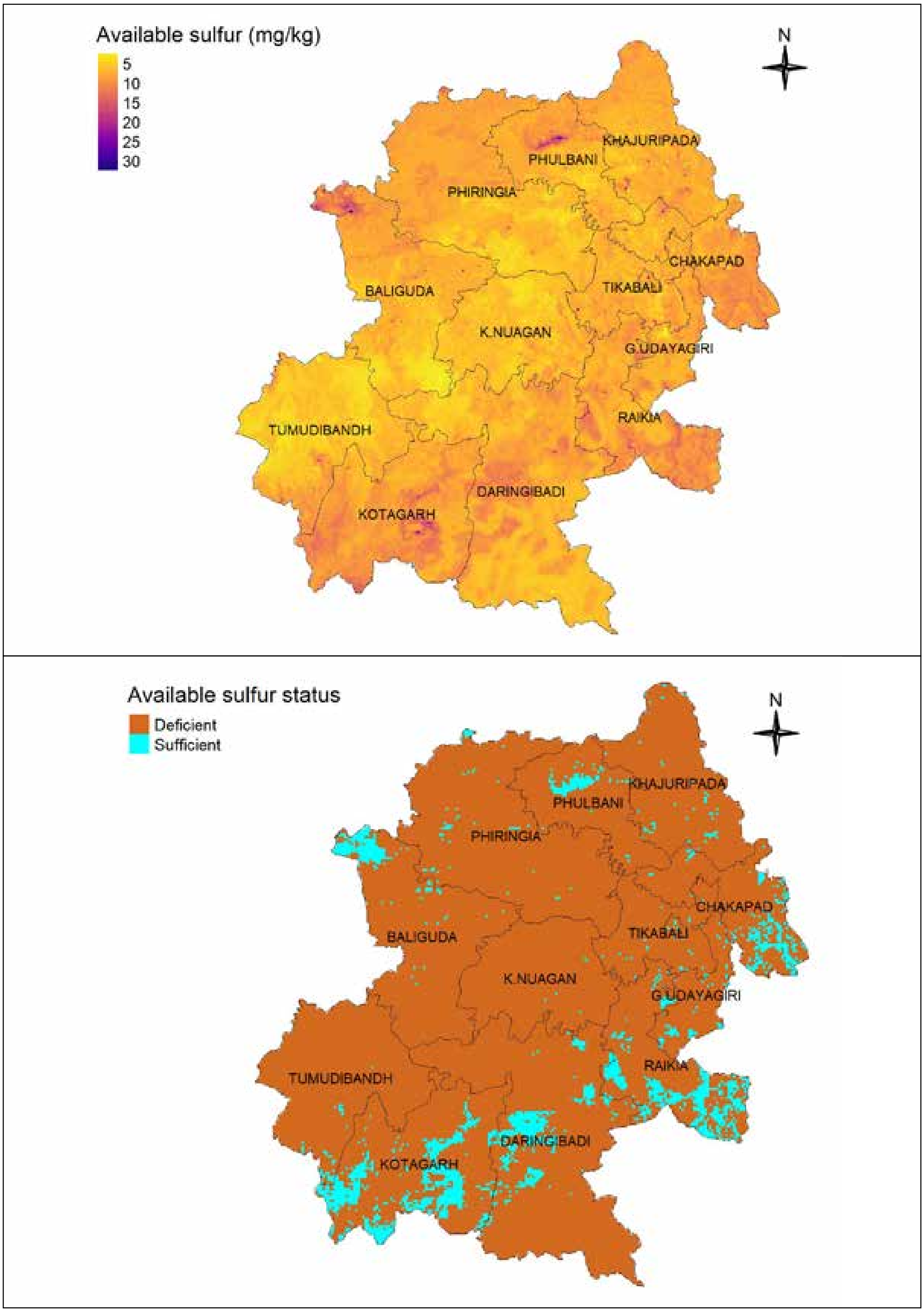


Figure 5.151. Status of available sulfur in soils of Kandhamal district.

Available Boron

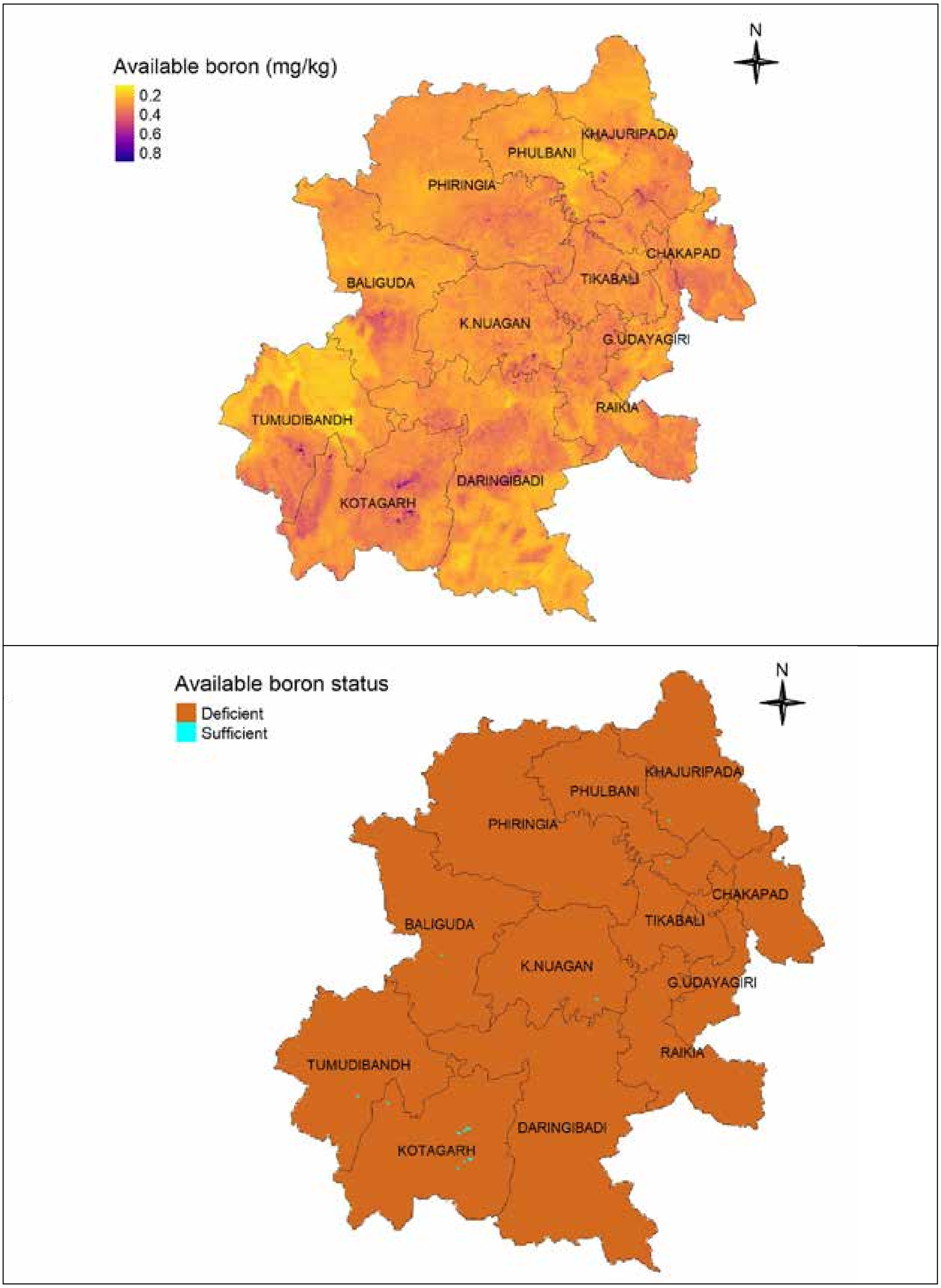


Figure 5.152. Status of available boron in soils of Kandhamal district.

Available Zinc

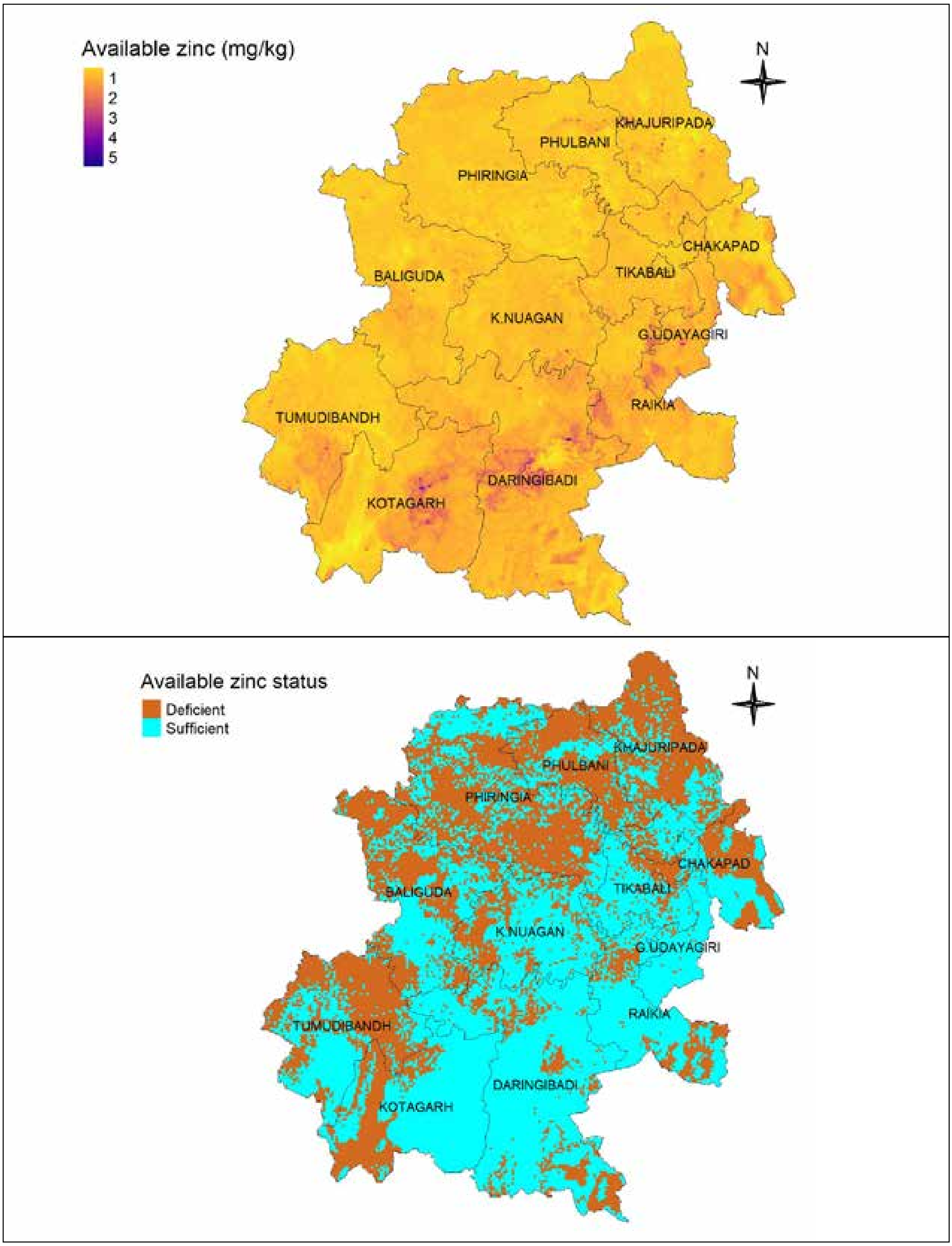


Figure 5.153. Status of available zinc in soils of Kandhamal district.

Kendrapara | pH

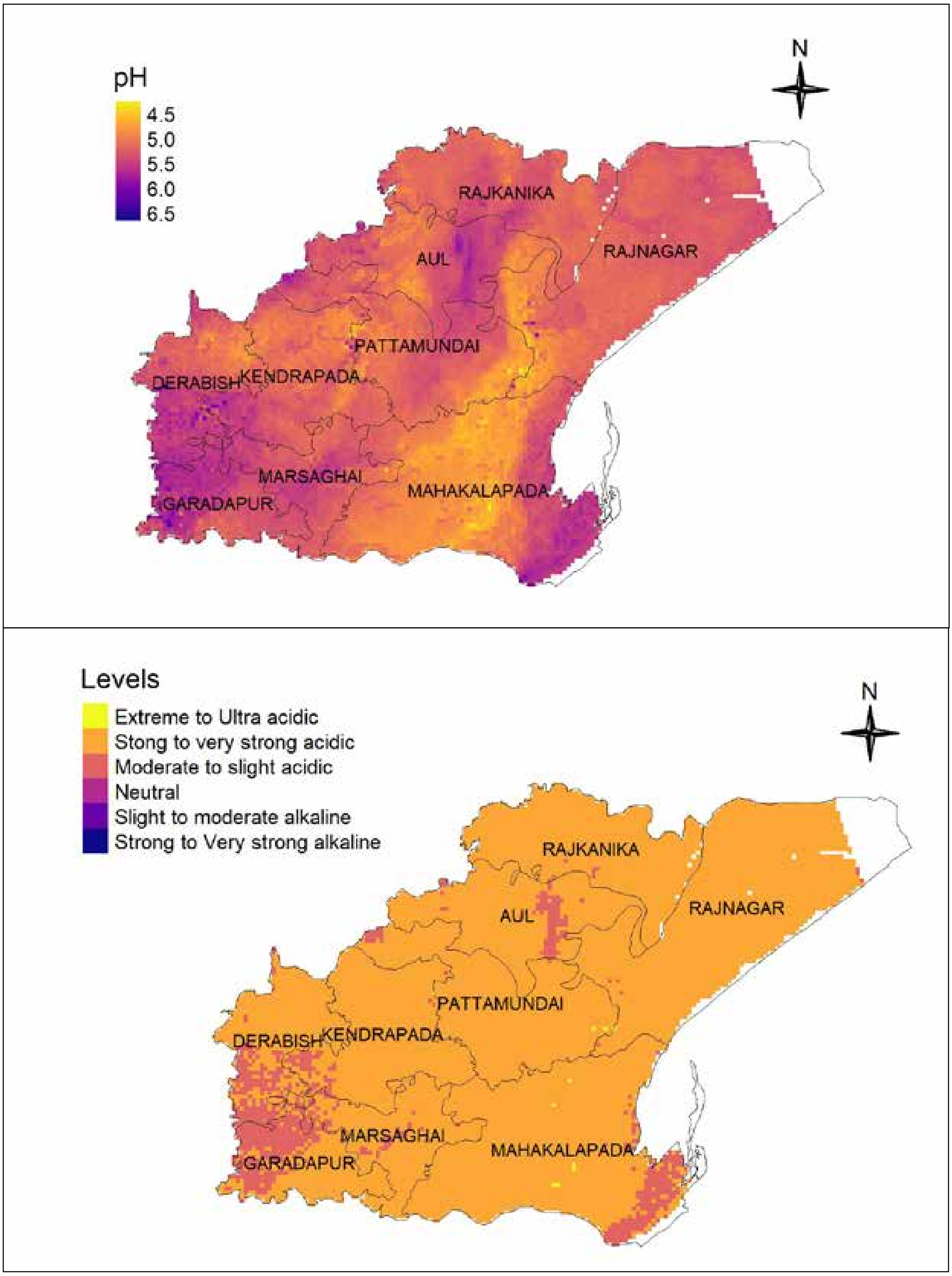


Figure 5.154. pH status in soils of Kendrapara district.

Electrical conductivity

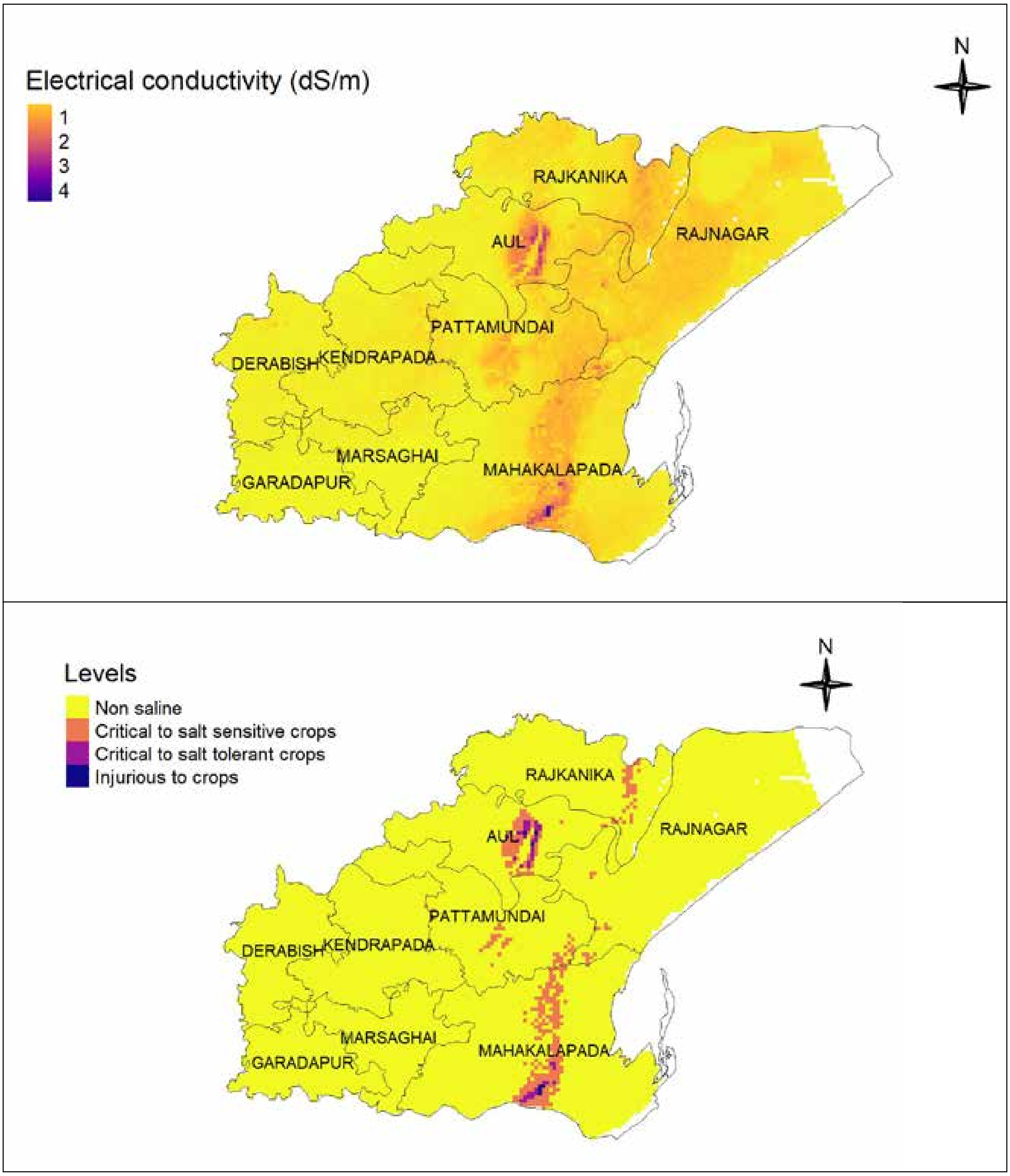


Figure 5.155. Status of electrical conductivity in soils of Kendrapara district.

Organic carbon

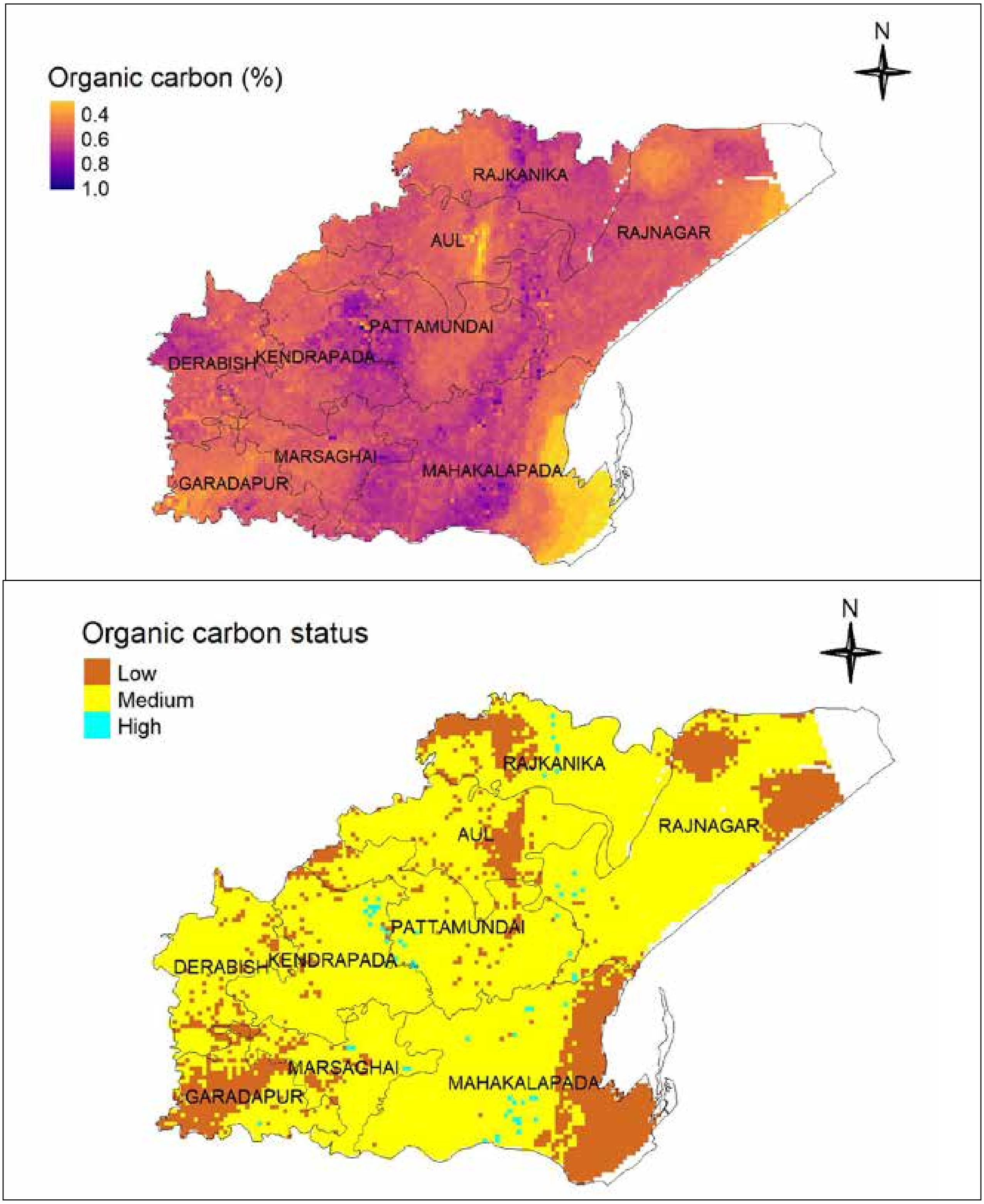


Figure 5.156. Organic carbon status in soils of Kendrapara district.

Available Phosphorous

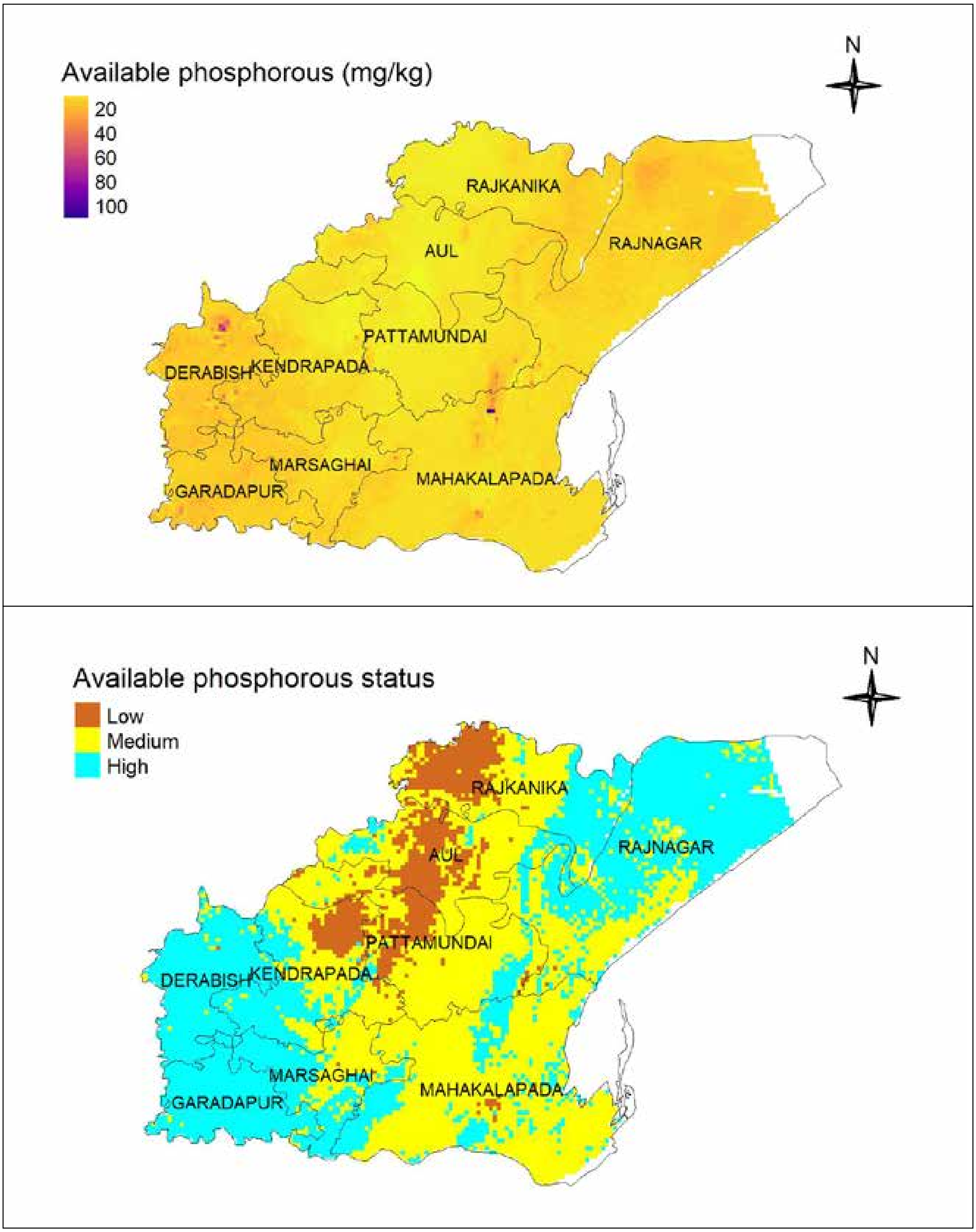


Figure 5.157. Status of available phosphorous in soils of Kendrapara district.

Exchangeable Potassium

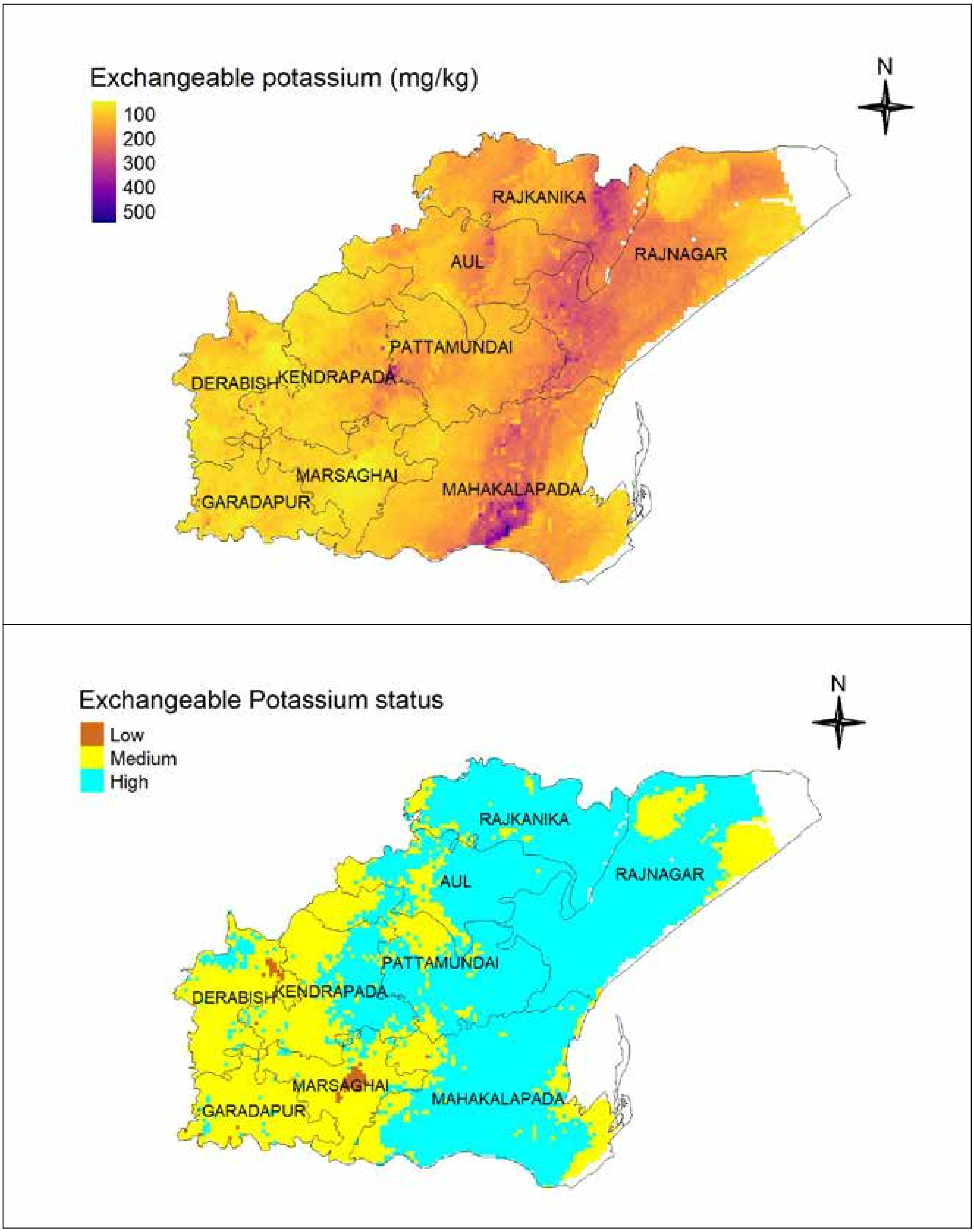


Figure 5.158. Status of exchangeable potassium in soils of Kendrapara district.

Available Sulfur

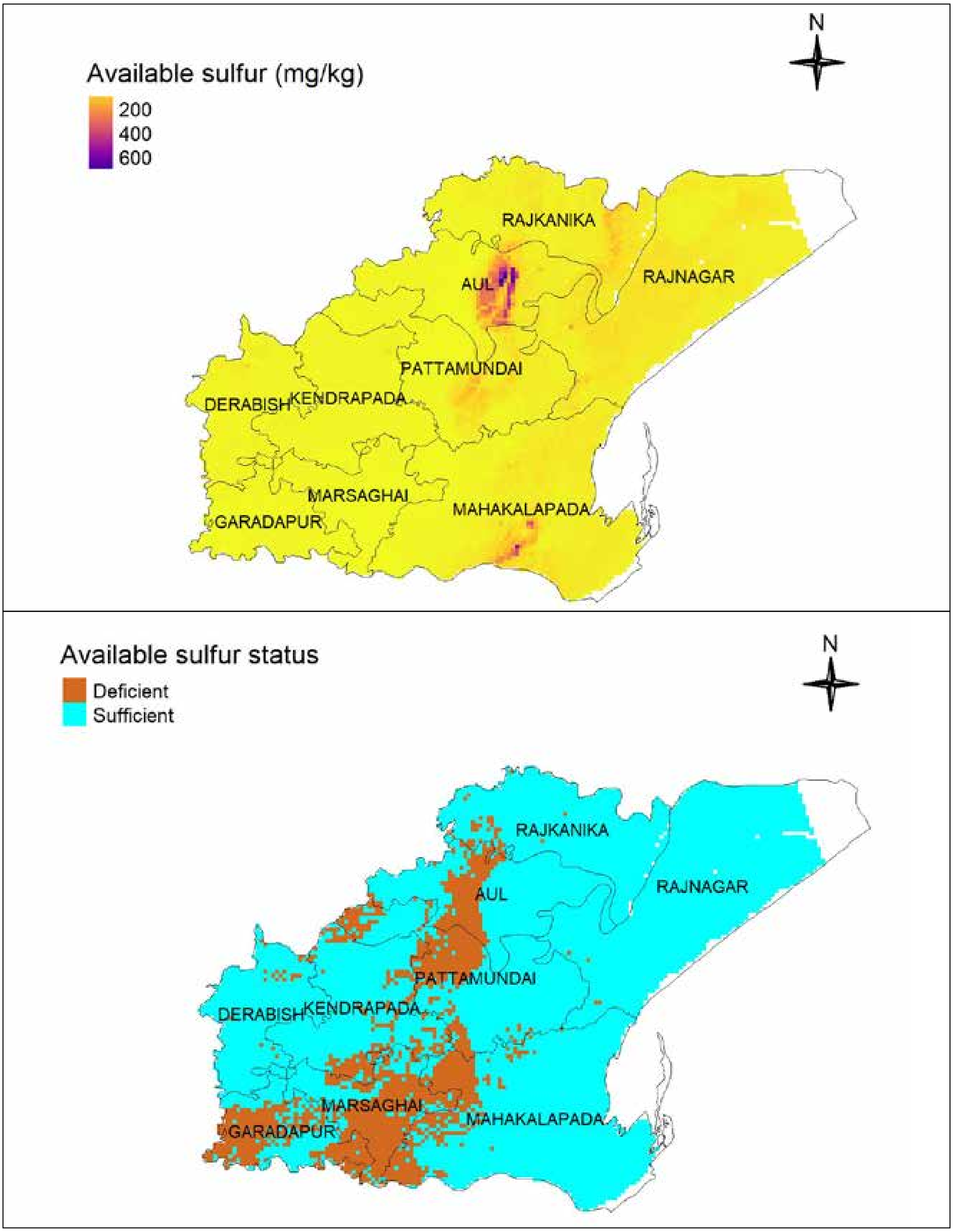


Figure 5.159. Status of available sulfur in soils of Kendrapara district.

Available Boron

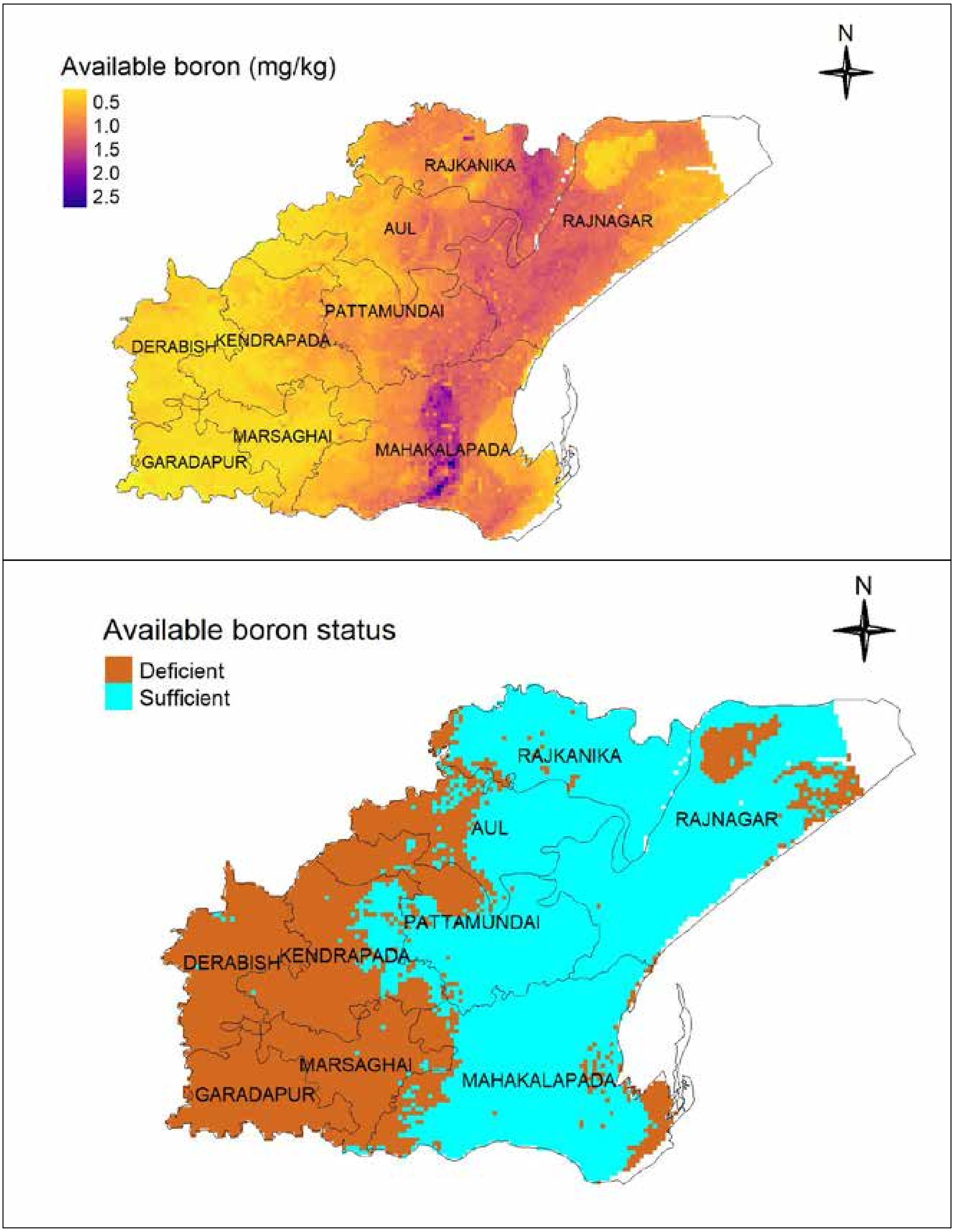


Figure 5.160. Status of available boron in soils of Kendrapara district.

Available Zinc

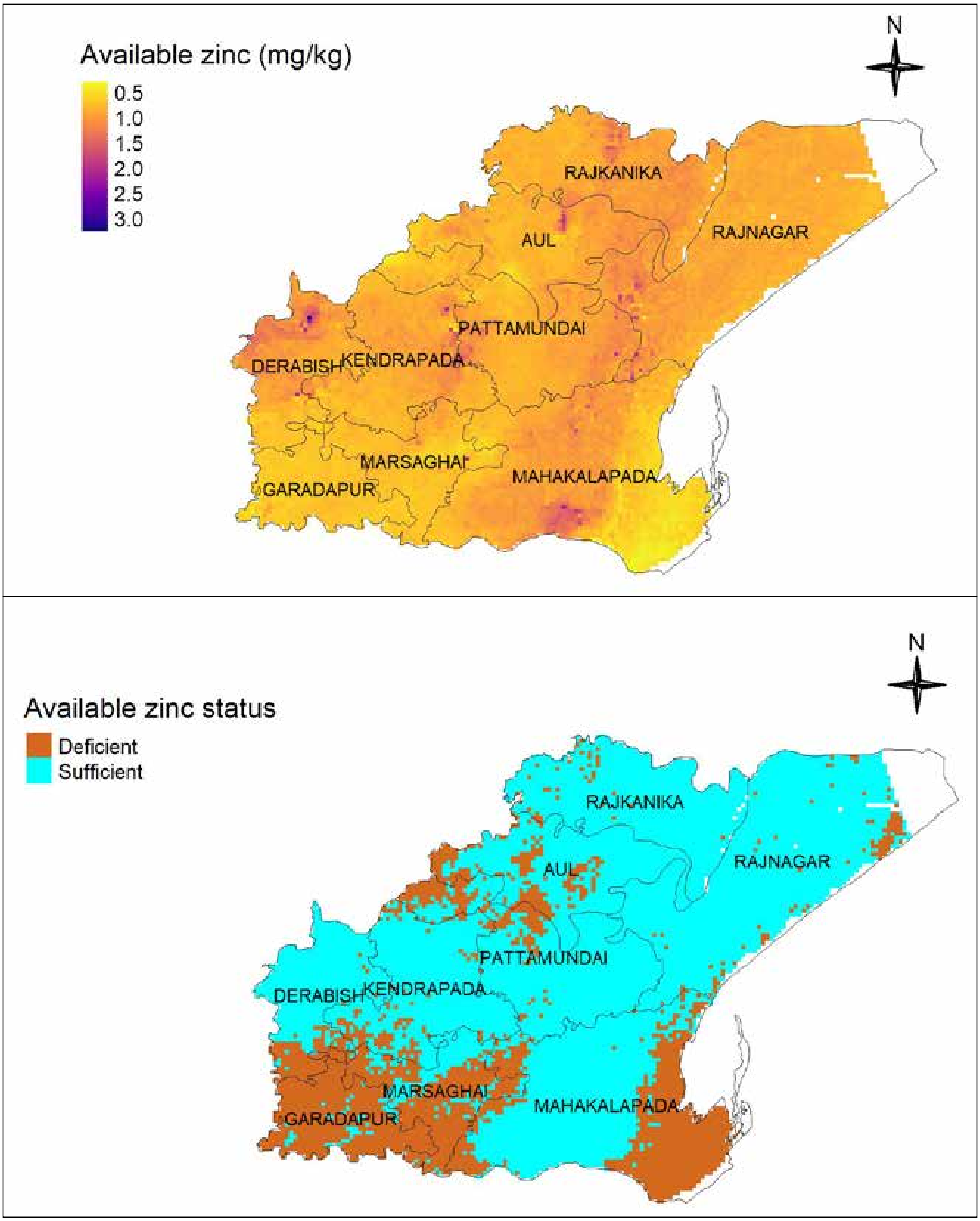


Figure 5.161. Status of available zinc in soils of Kendrapara district.

Kendujhar | pH

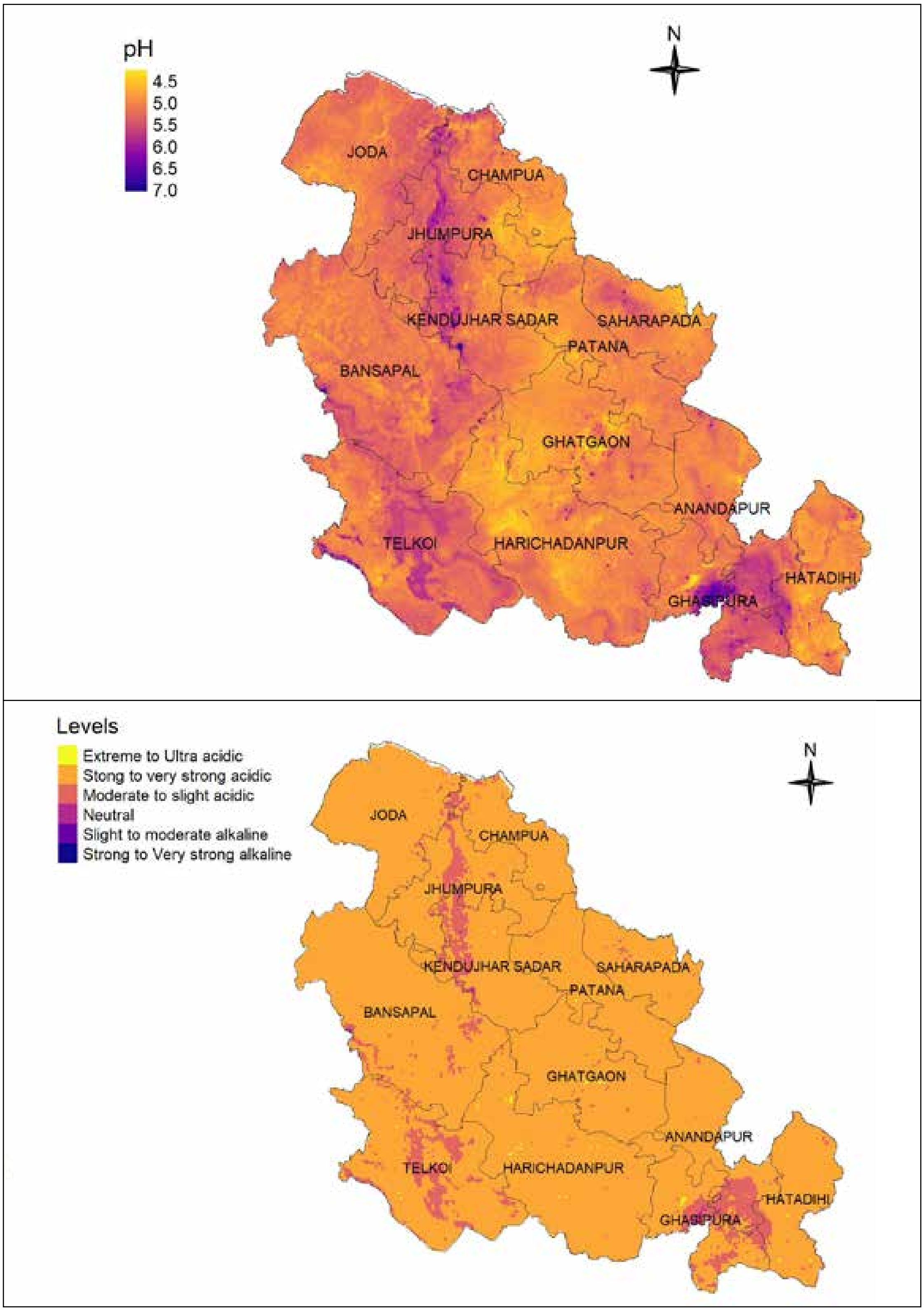


Figure 5.162. pH status in soils of Kendujhar district.

Electrical conductivity

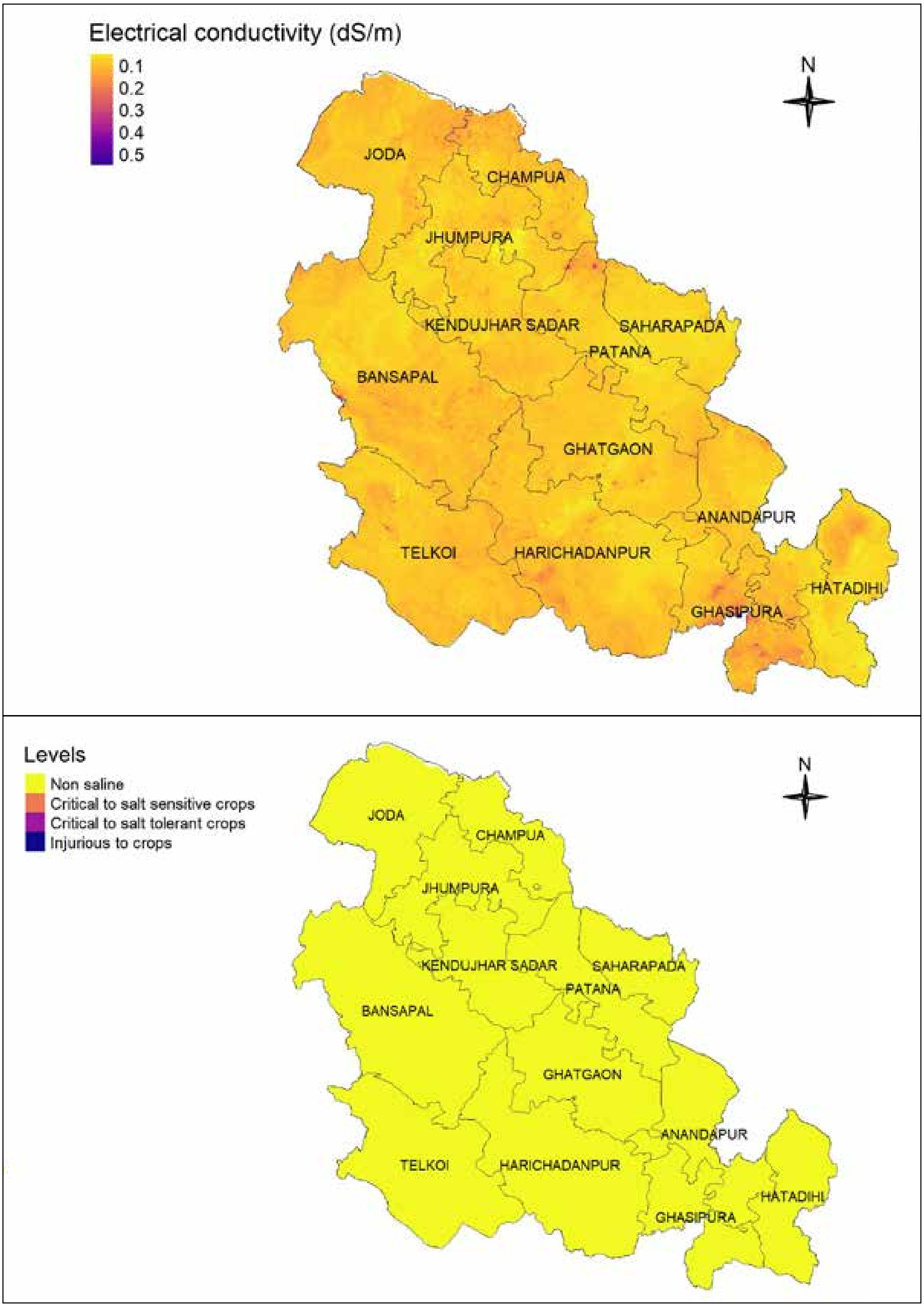


Figure 5.163. Status of electrical conductivity in soils of Kendujhar district.

Organic carbon

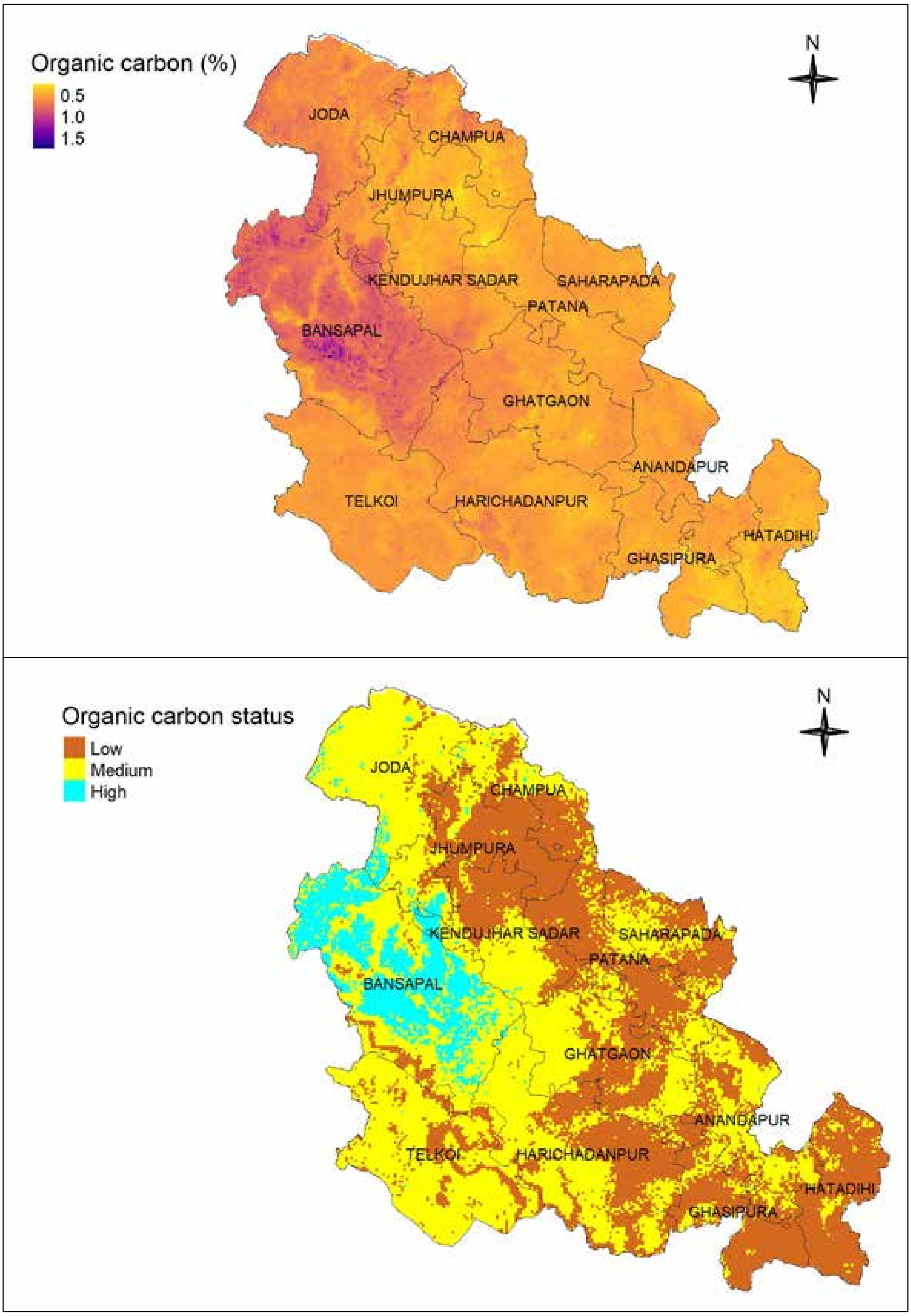


Figure 5.164. Organic carbon status in soils of Kendujhar district.

Available Phosphorous

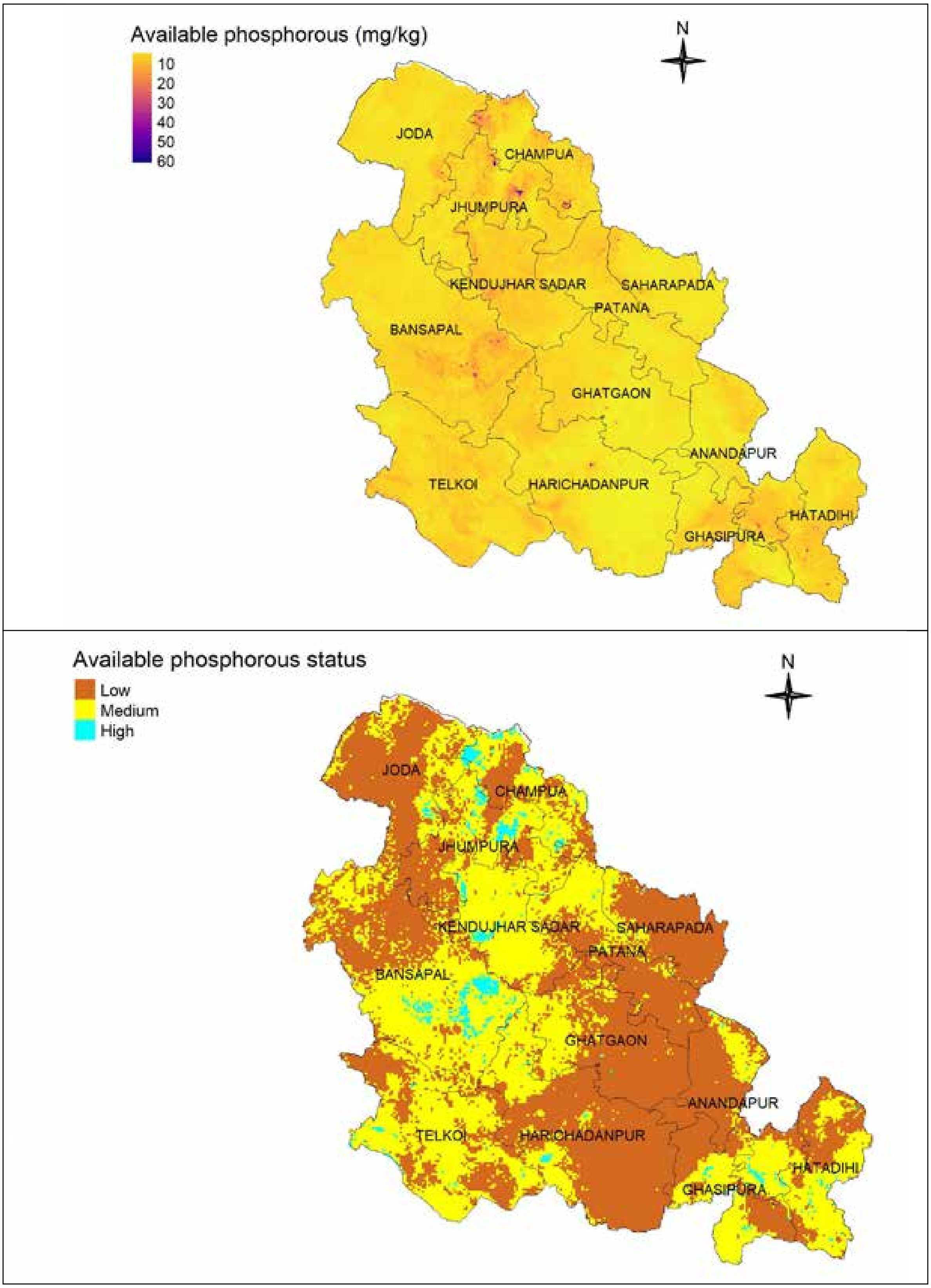


Figure 5.165. Status of available phosphorous in soils of Kendujhar district.

Exchangeable Potassium

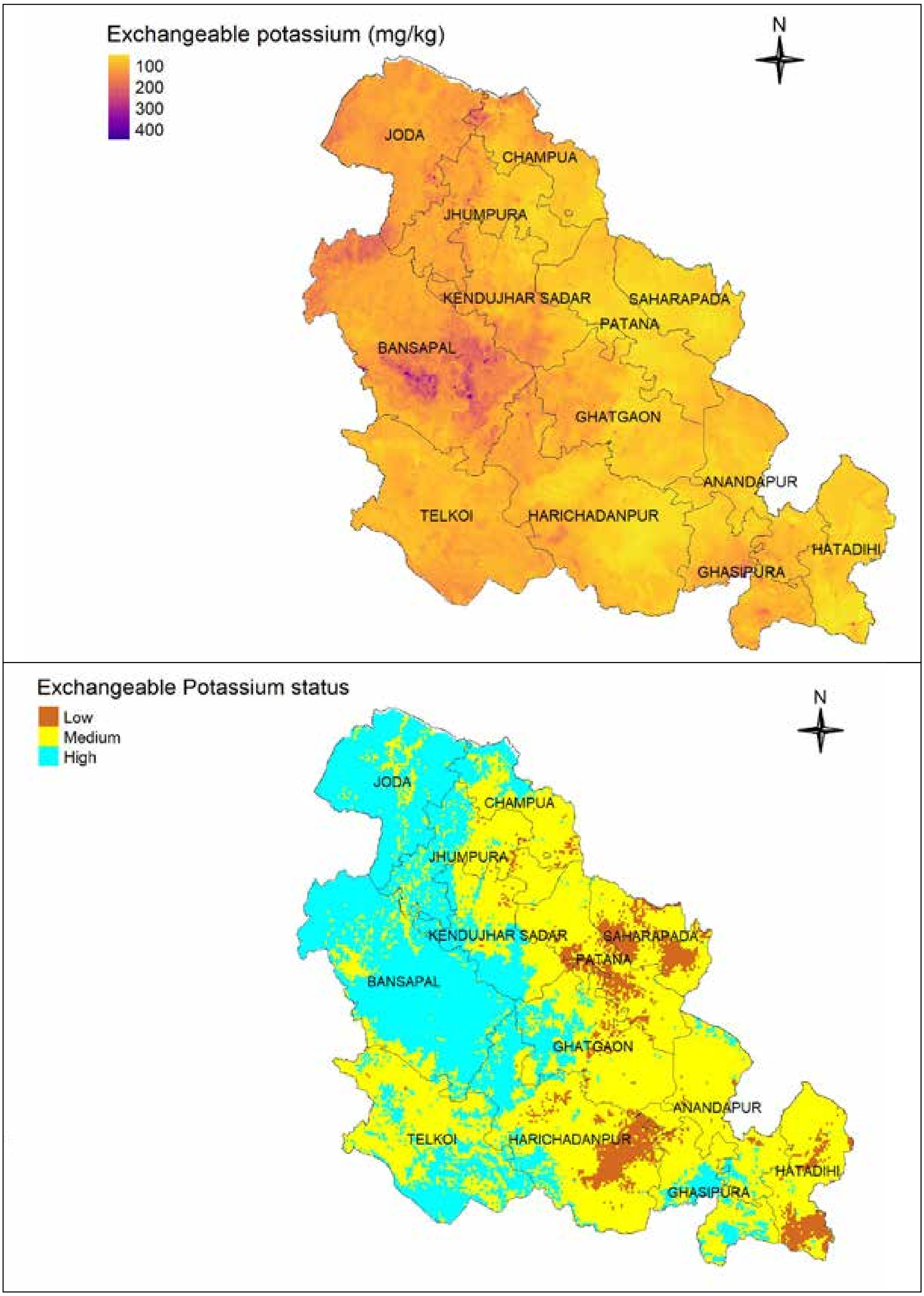


Figure 5.166. Status of exchangeable potassium in soils of Kendujhar district.

Available Sulfur

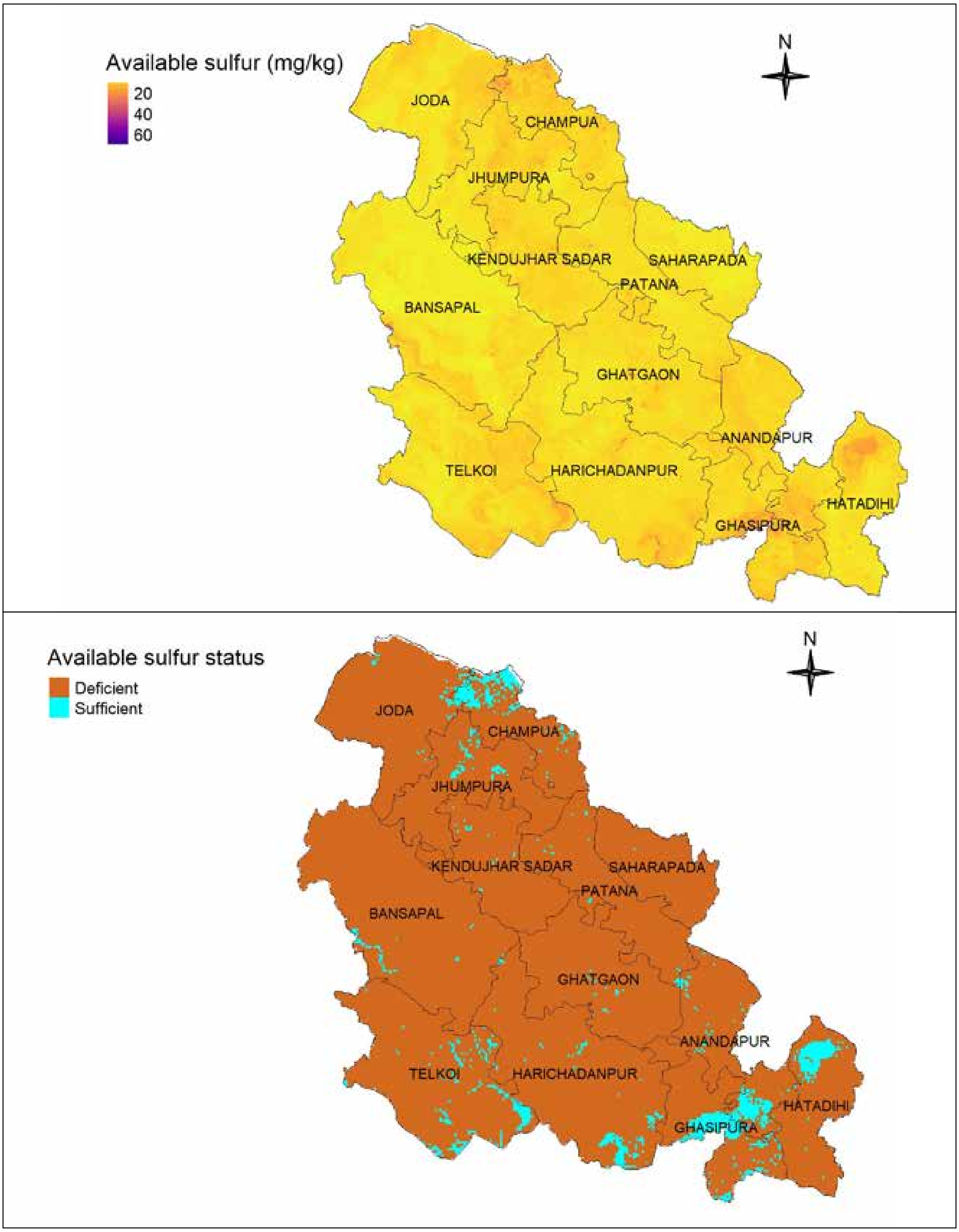


Figure 5.167. Status of available sulfur in soils of Kendujhar district.

Available Boron

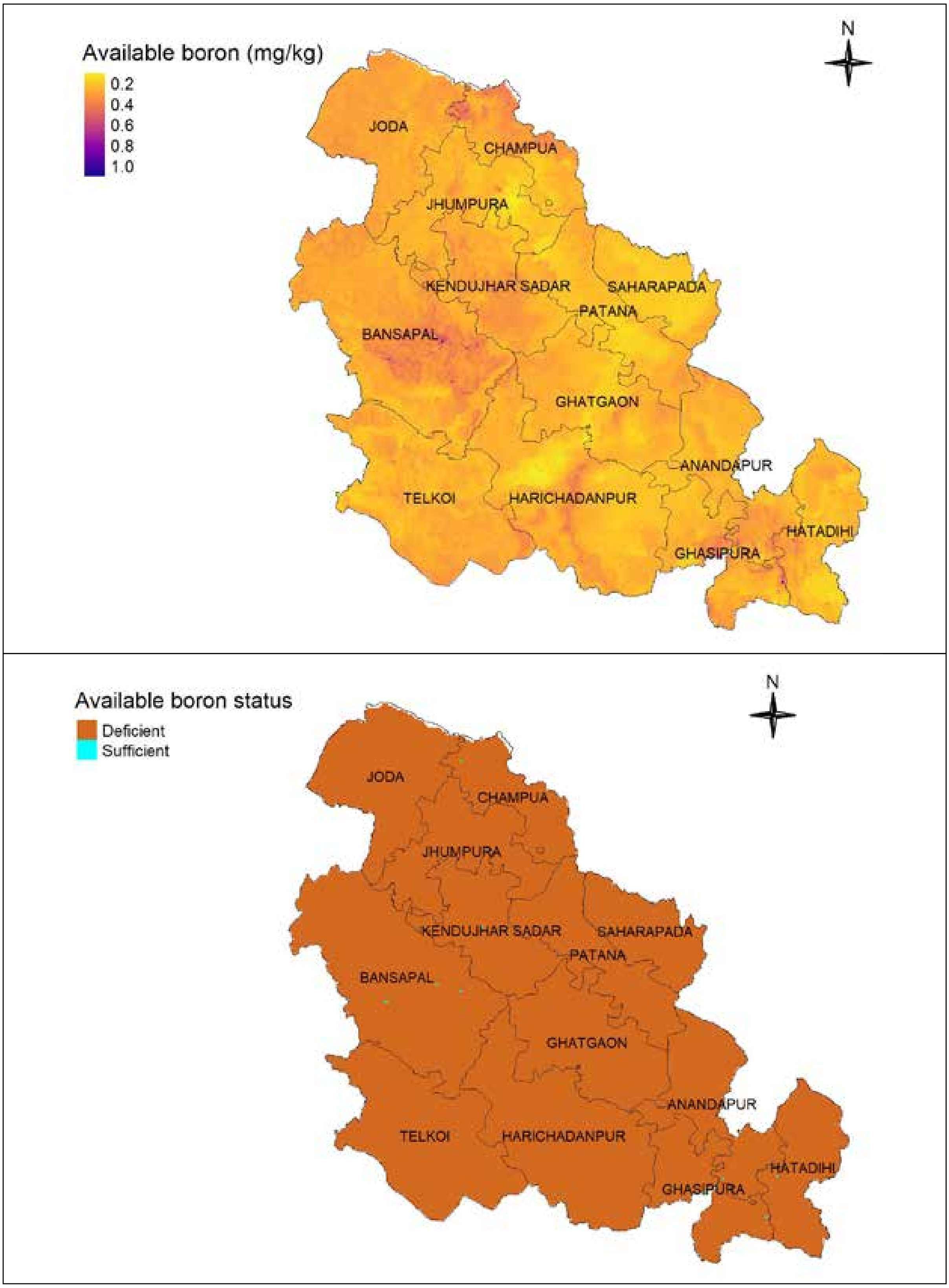


Figure 5.168. Status of available boron in soils of Kendujhar district.

Available Zinc

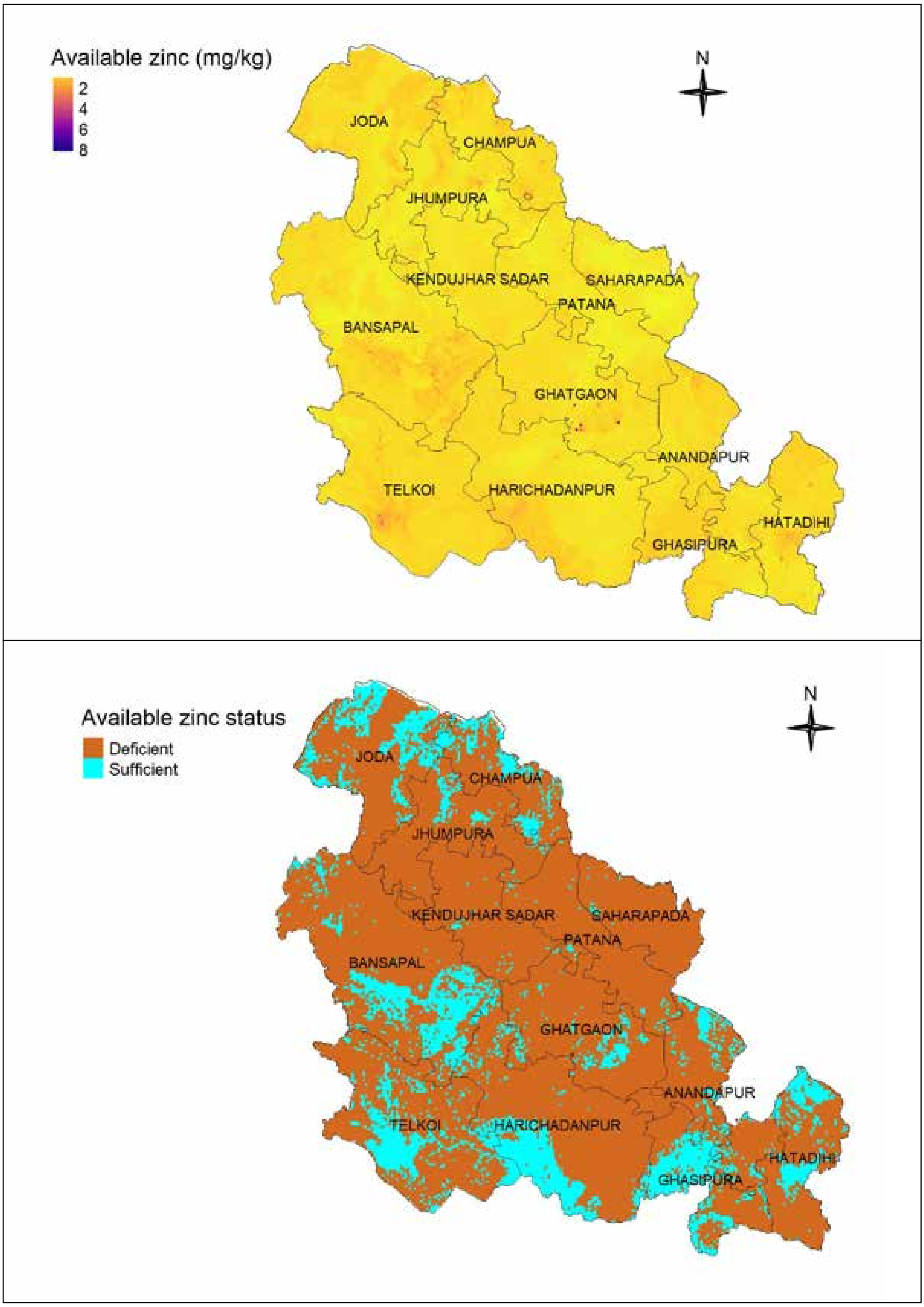


Figure 5.169. Status of available zinc in soils of Kendujhar district.

Khorda | pH

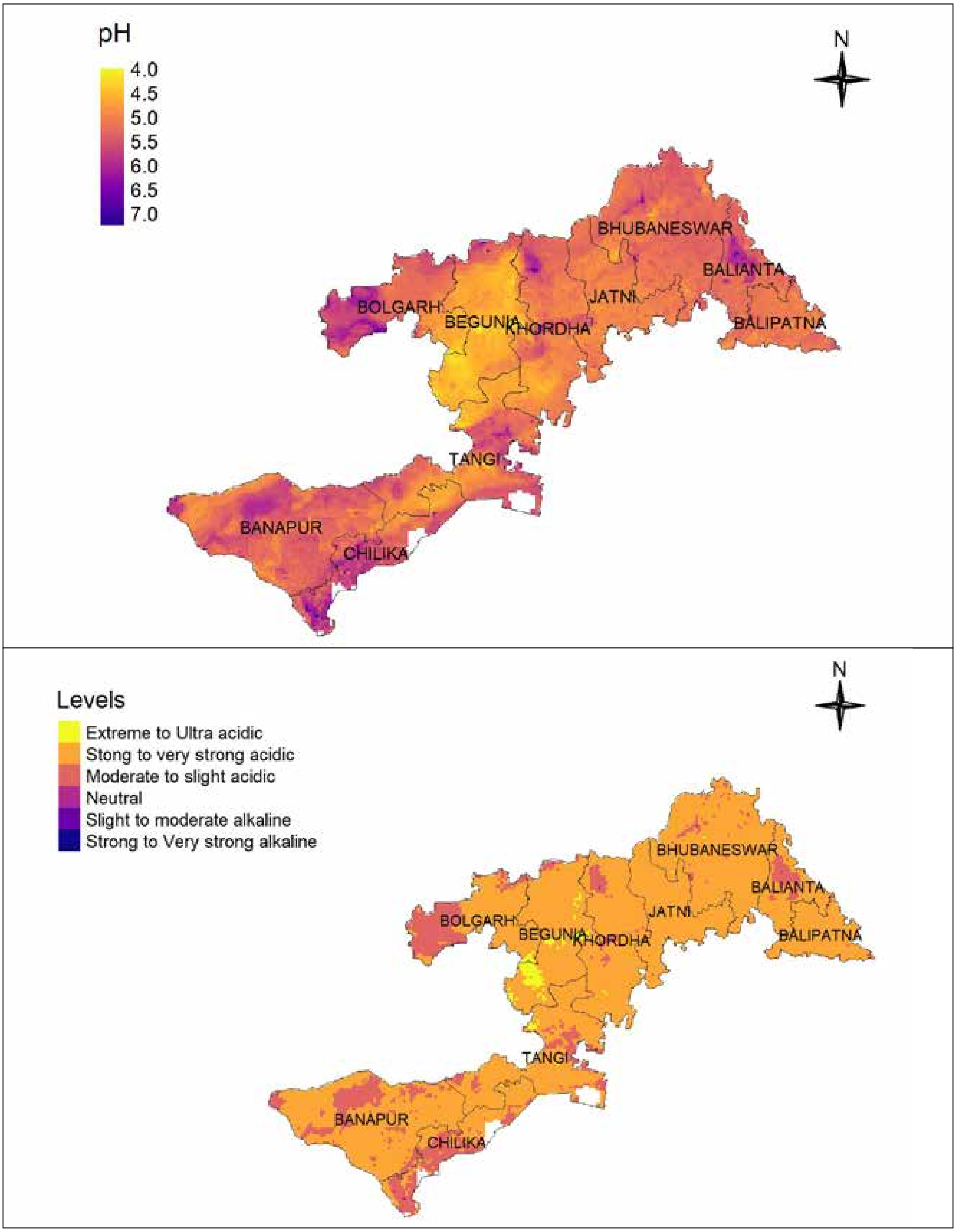


Figure 5.170. pH status in soils of Khorda district.

Electrical conductivity

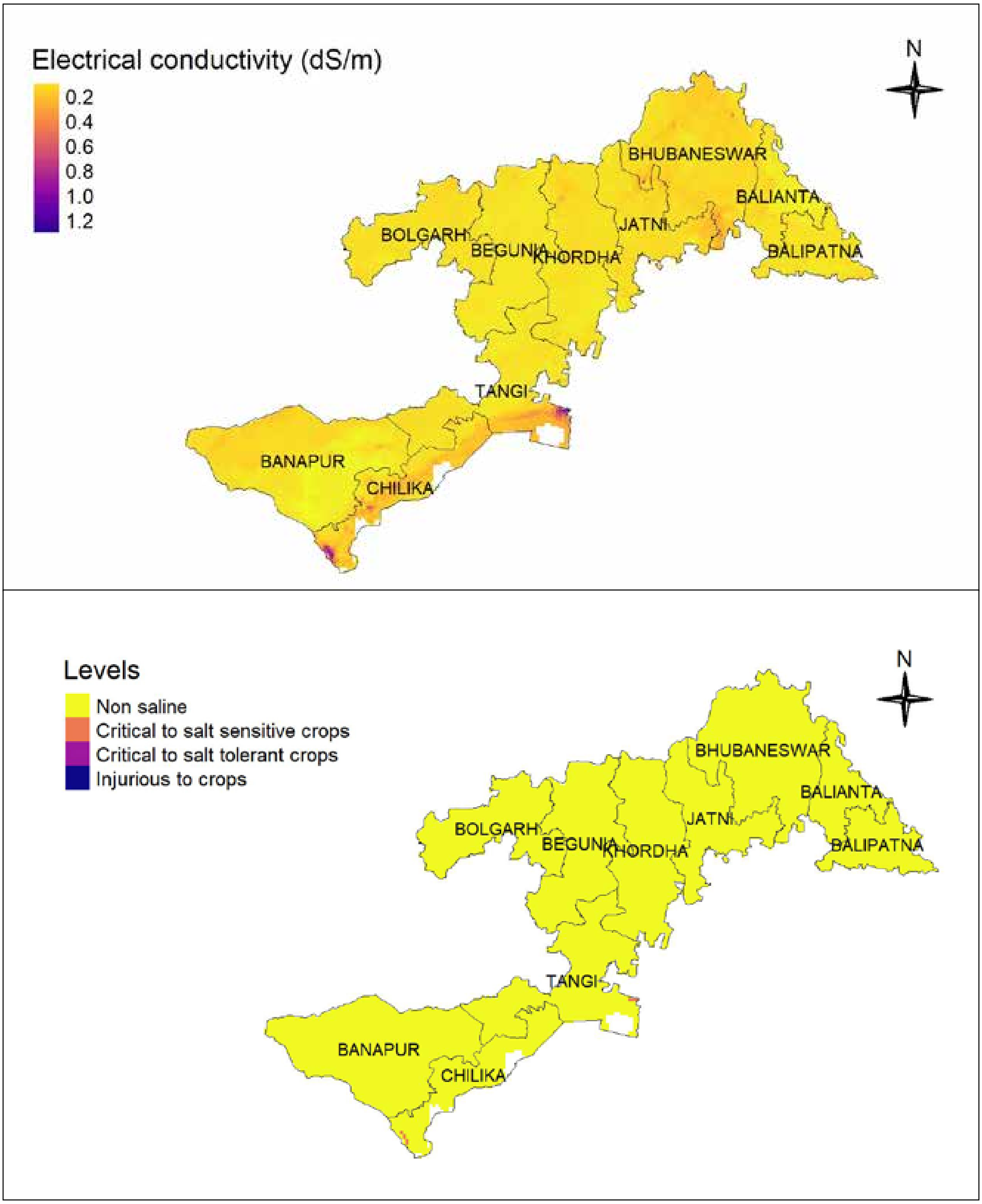


Figure 5.171. Status of electrical conductivity in soils of Khorda district

Organic carbon

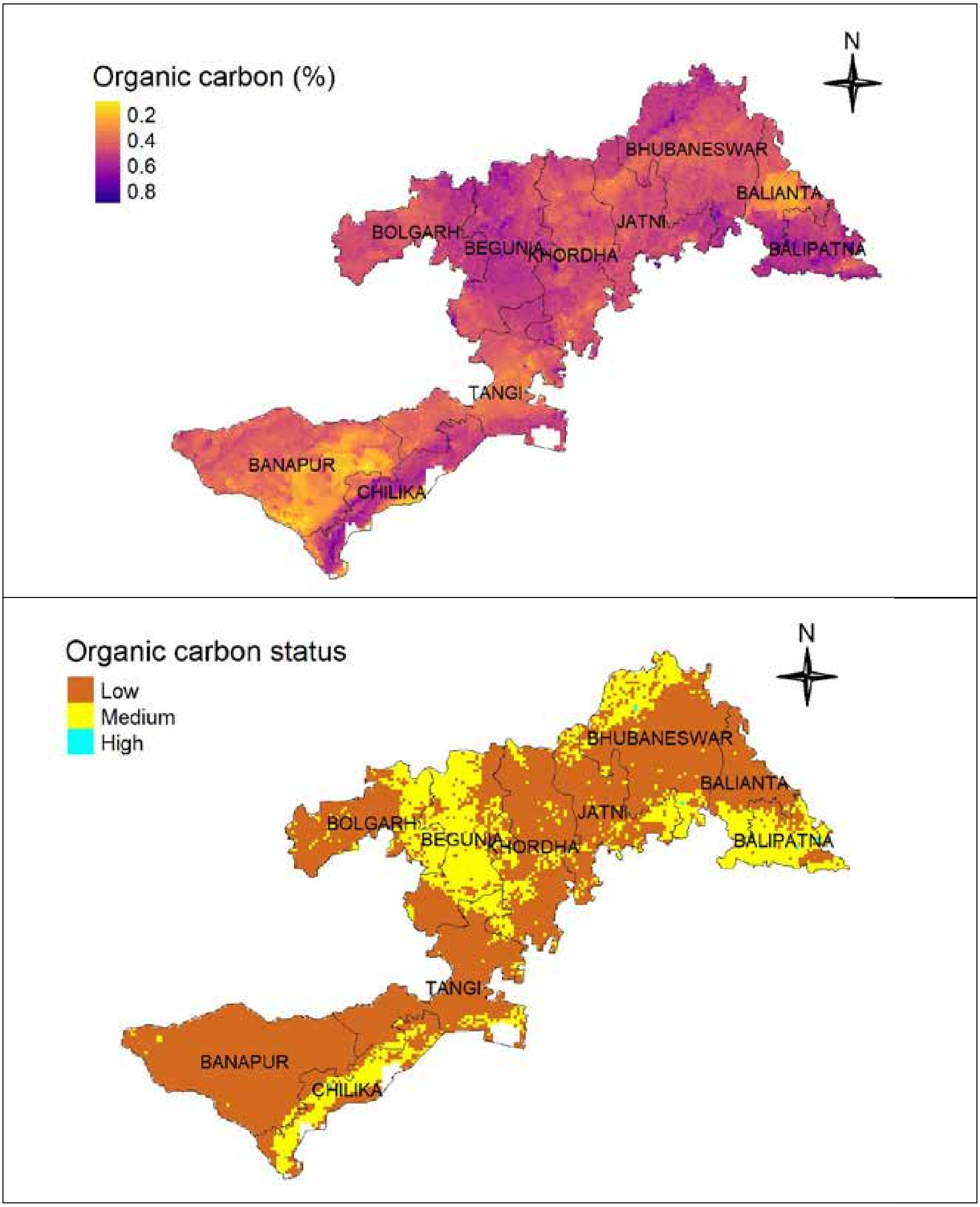


Figure 5.172. Organic carbon status in soils of Khorda district.

Available Phosphorous

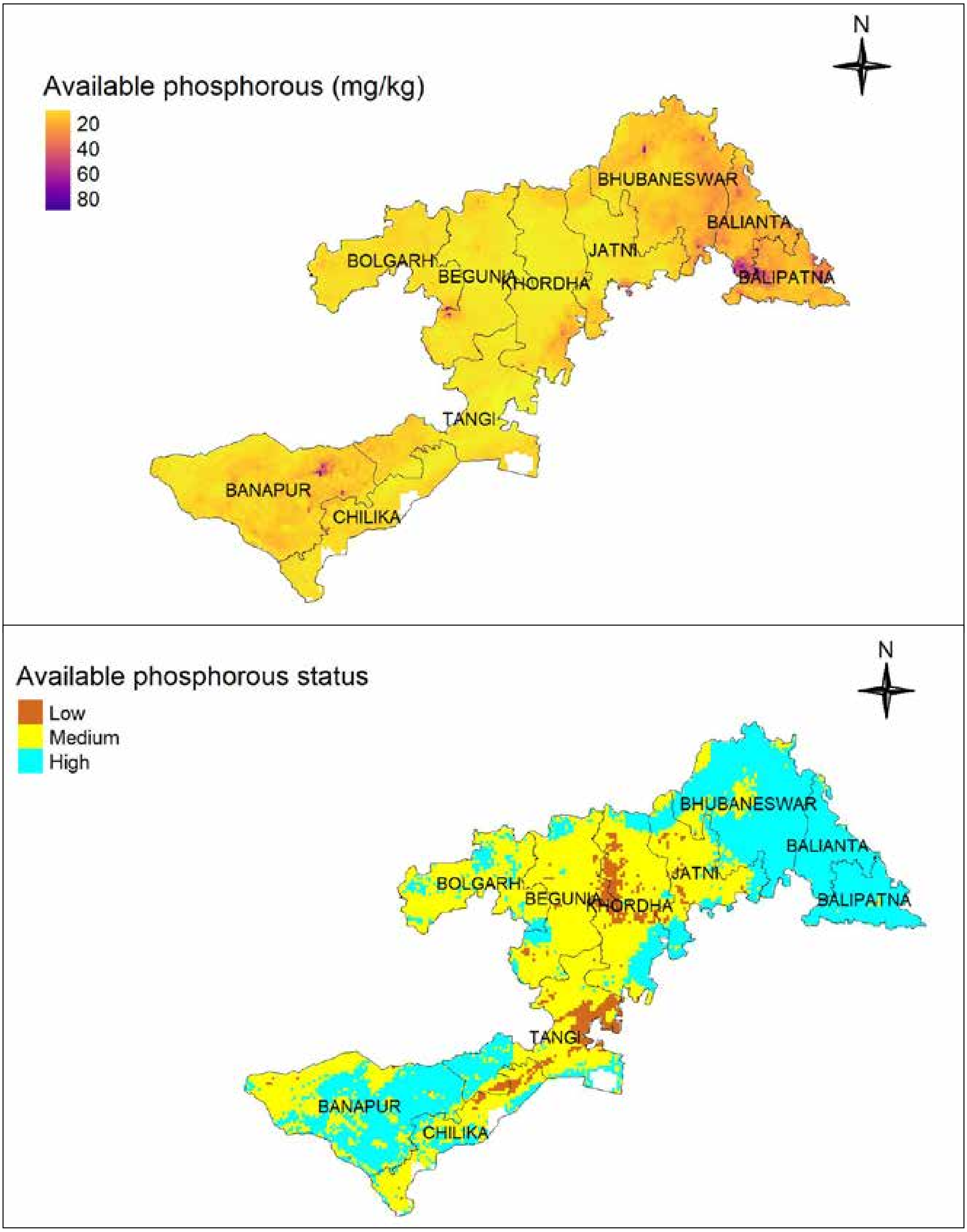


Figure 5.173. Status of available phosphorous in soils of Khorda district.

Exchangeable Potassium

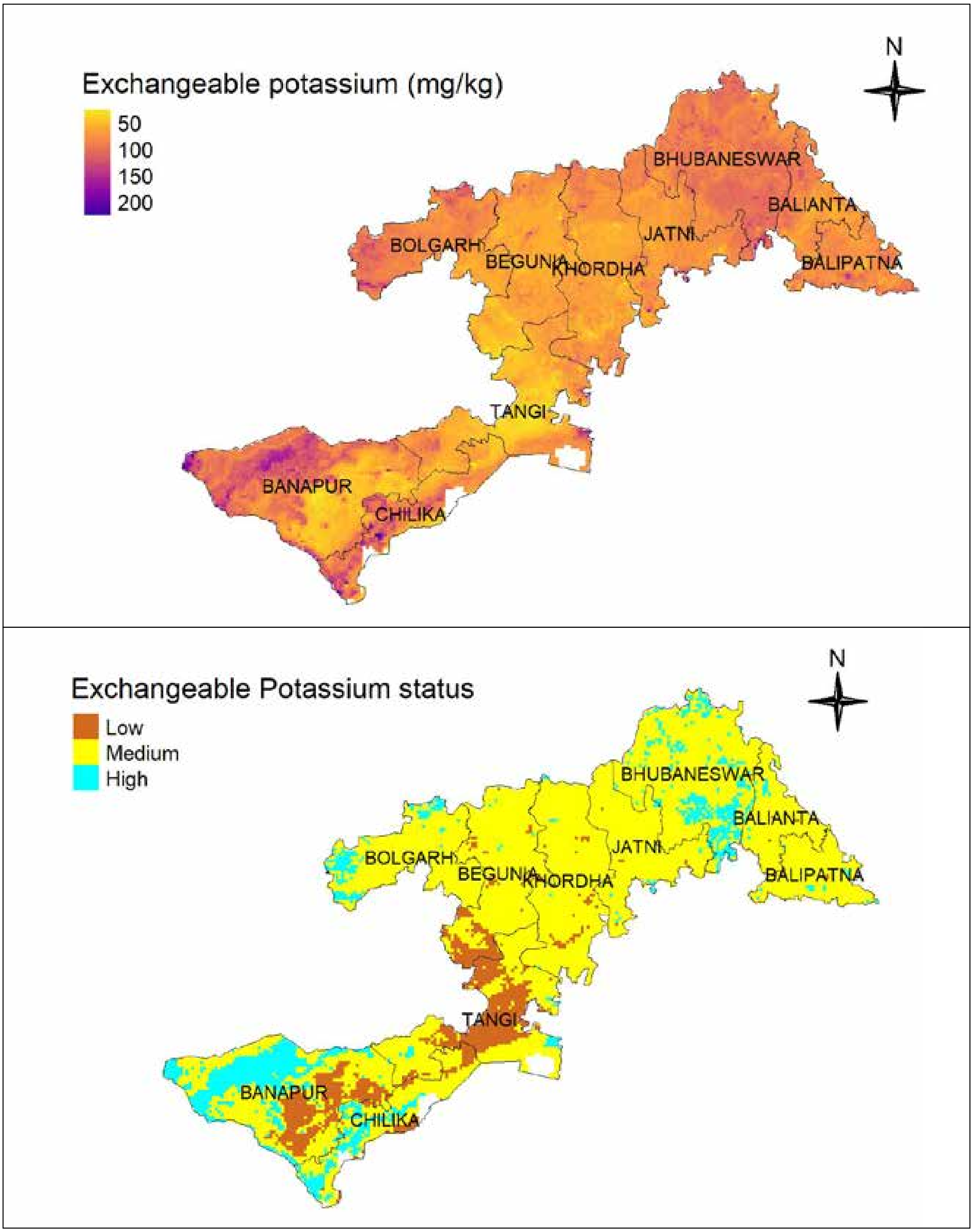


Figure 5.174. Status of exchangeable potassium in soils of Khorda district.

Available Sulfur

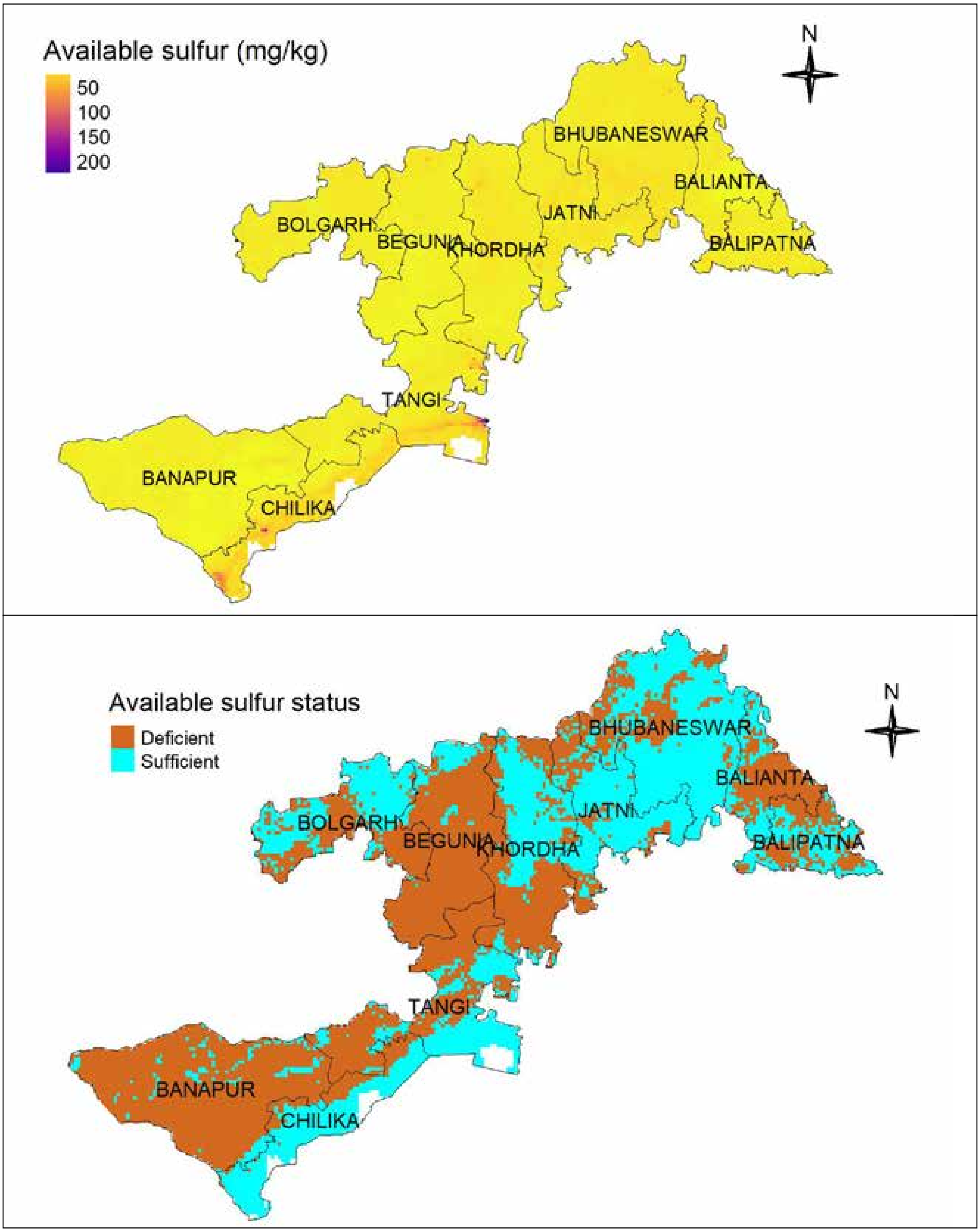


Figure 5.175. Status of available sulfur in soils of Khorda district.

Available Boron

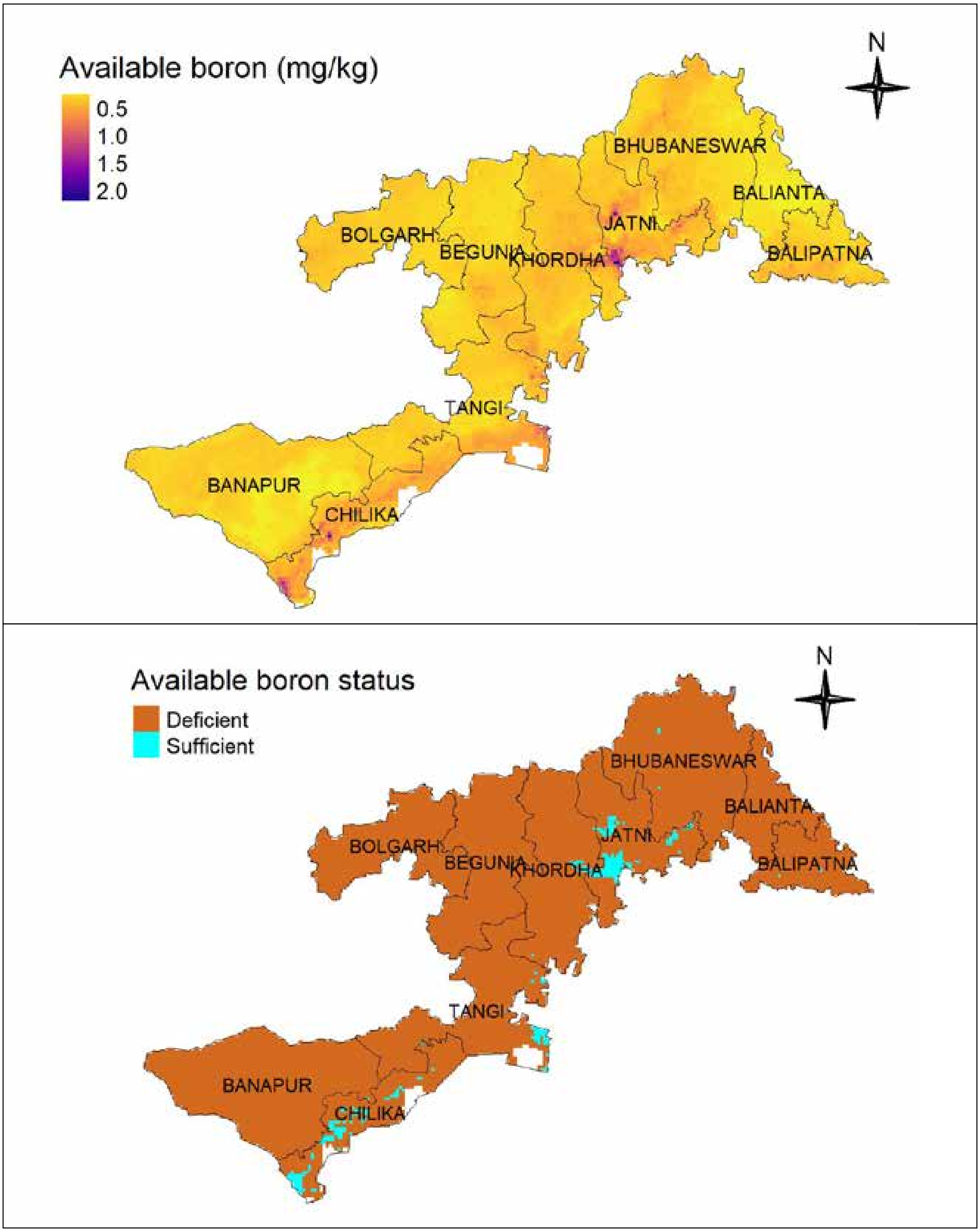


Figure 5.176. Status of available boron in soils of Khorda district.

Available Zinc

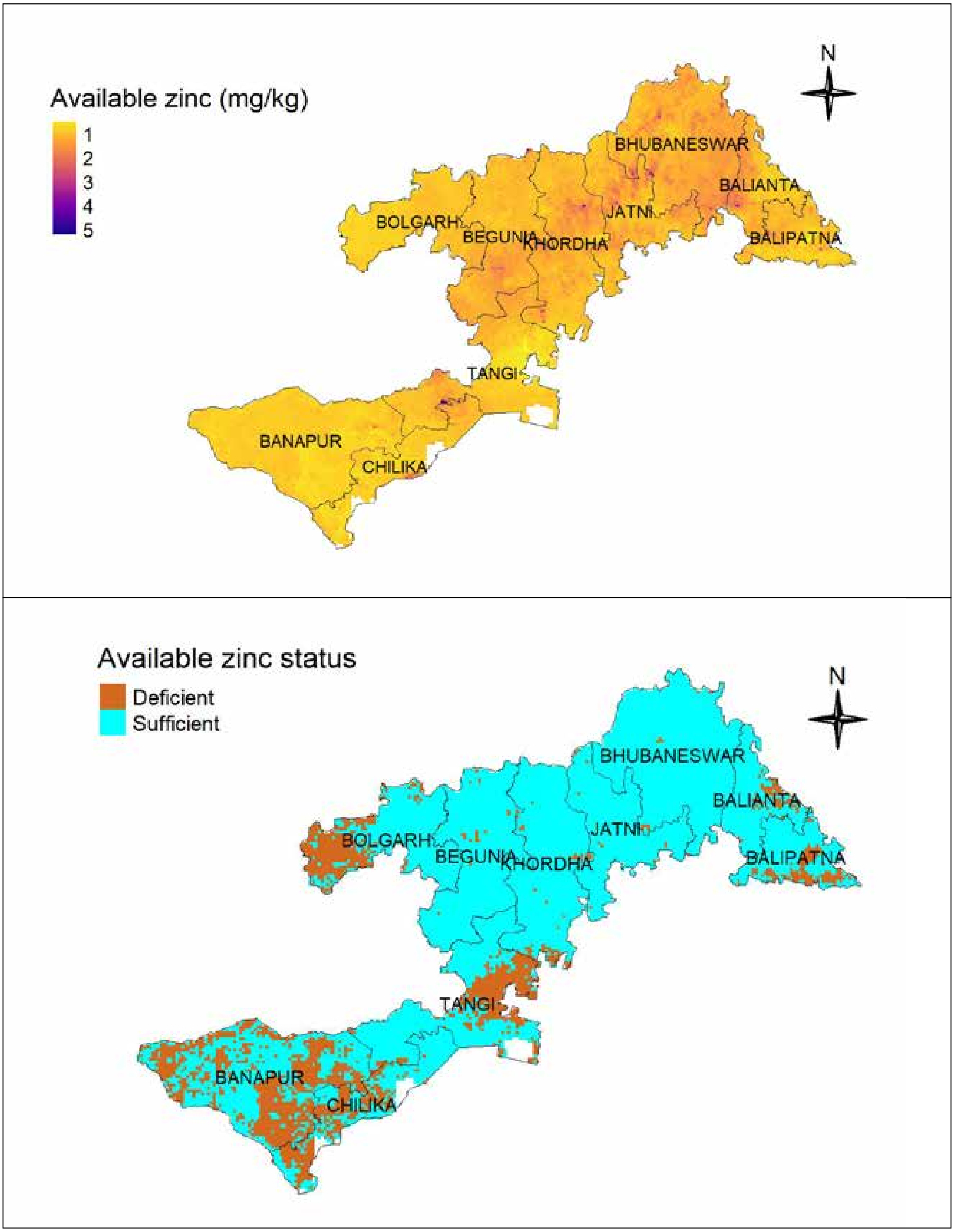


Figure 5.177. Status of available zinc in soils of Khorda district.

Koraput | pH

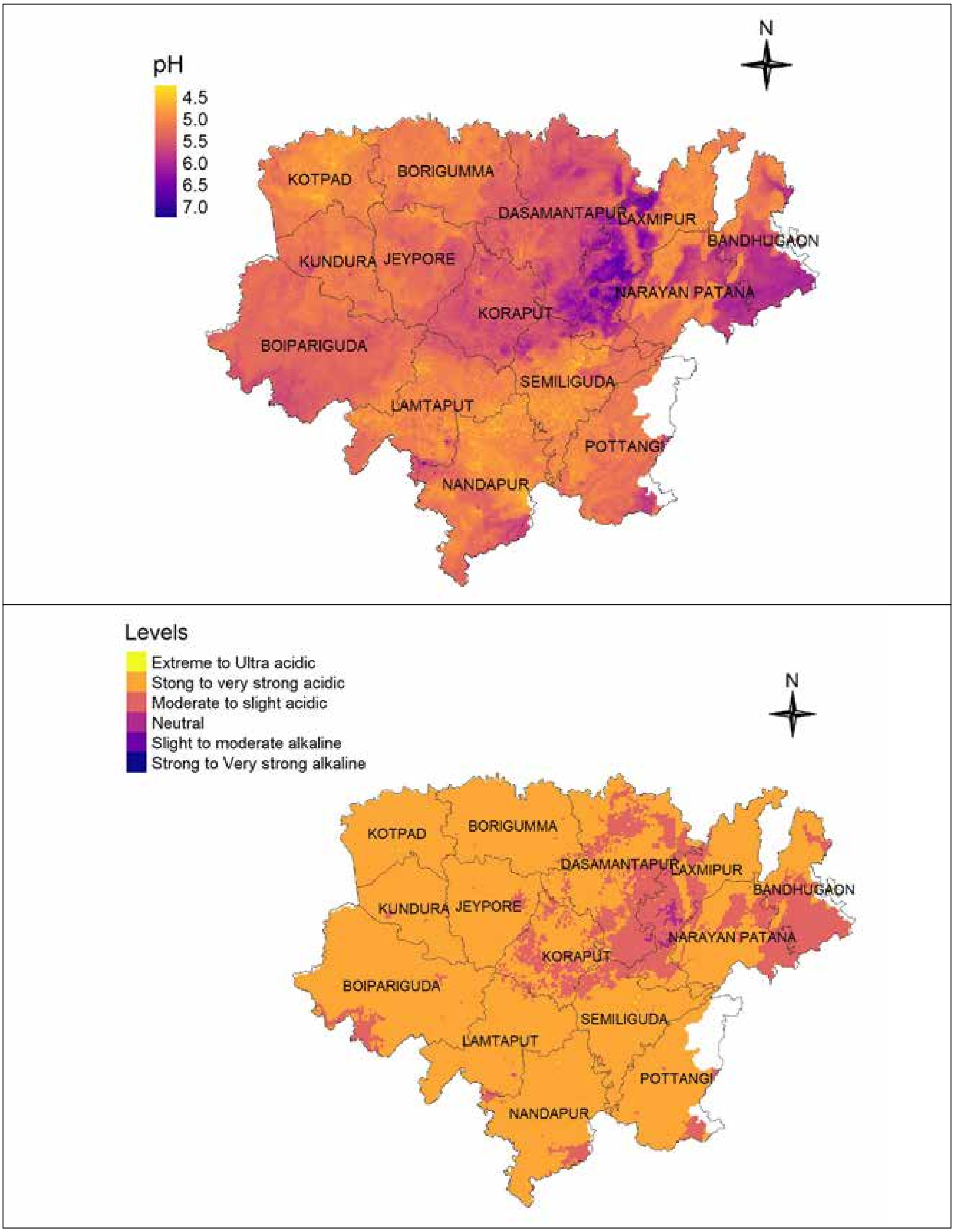


Figure 5.178. pH status in soils of Koraput district.

Electrical conductivity

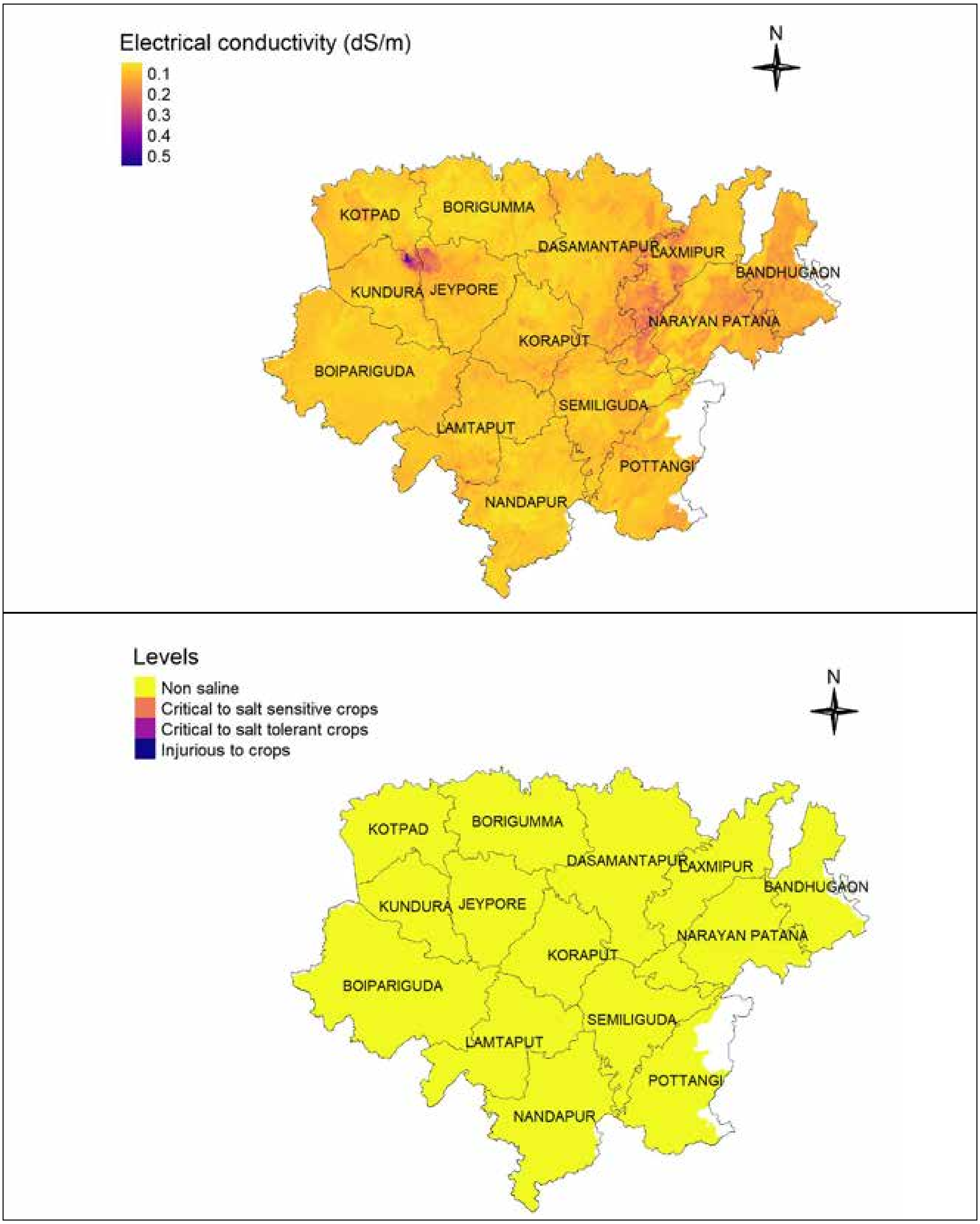


Figure 5.179. Status of electrical conductivity in soils of Koraput district.

Organic carbon

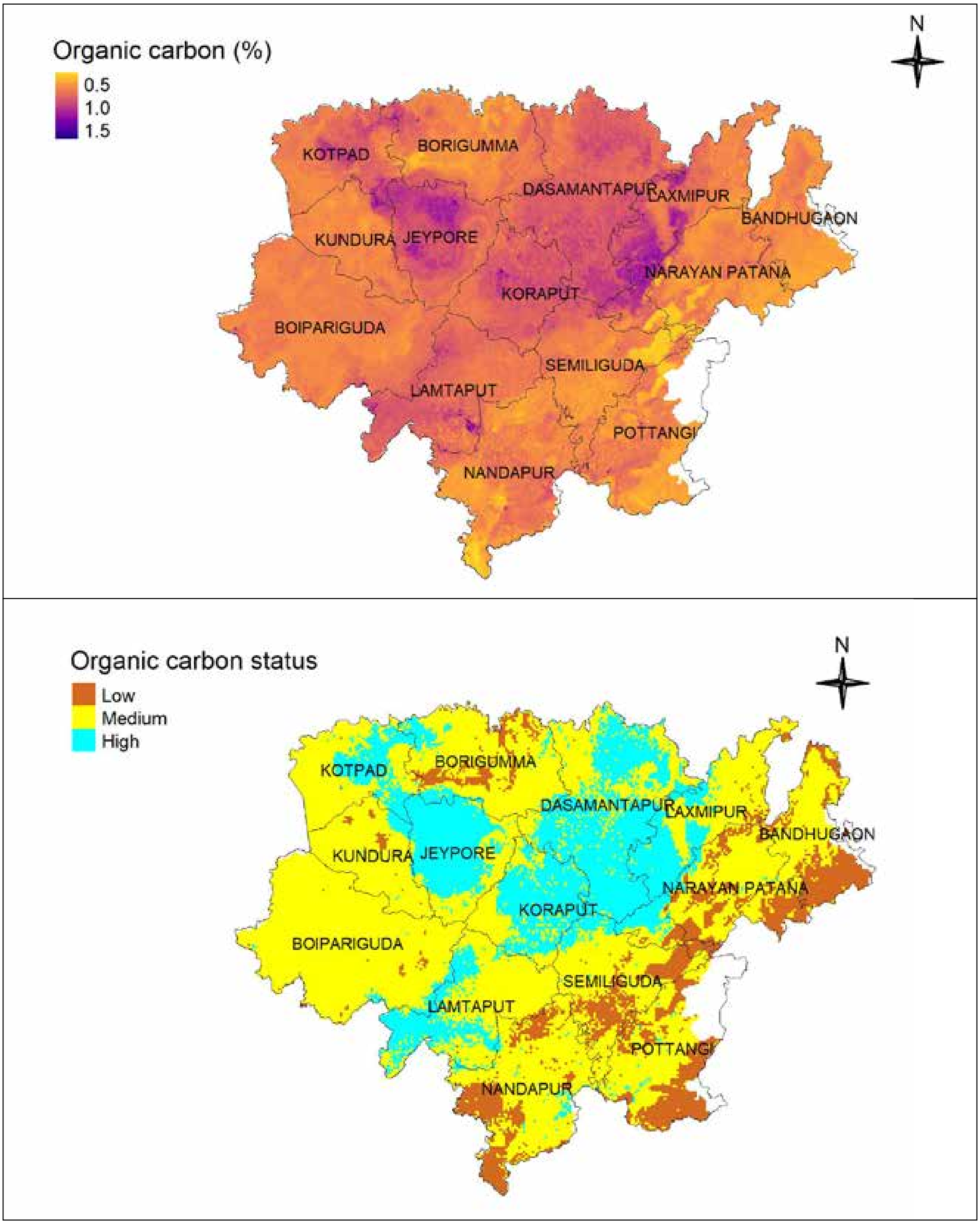


Figure 5.180. Organic carbon status in soils of Koraput district.

Available Phosphorous

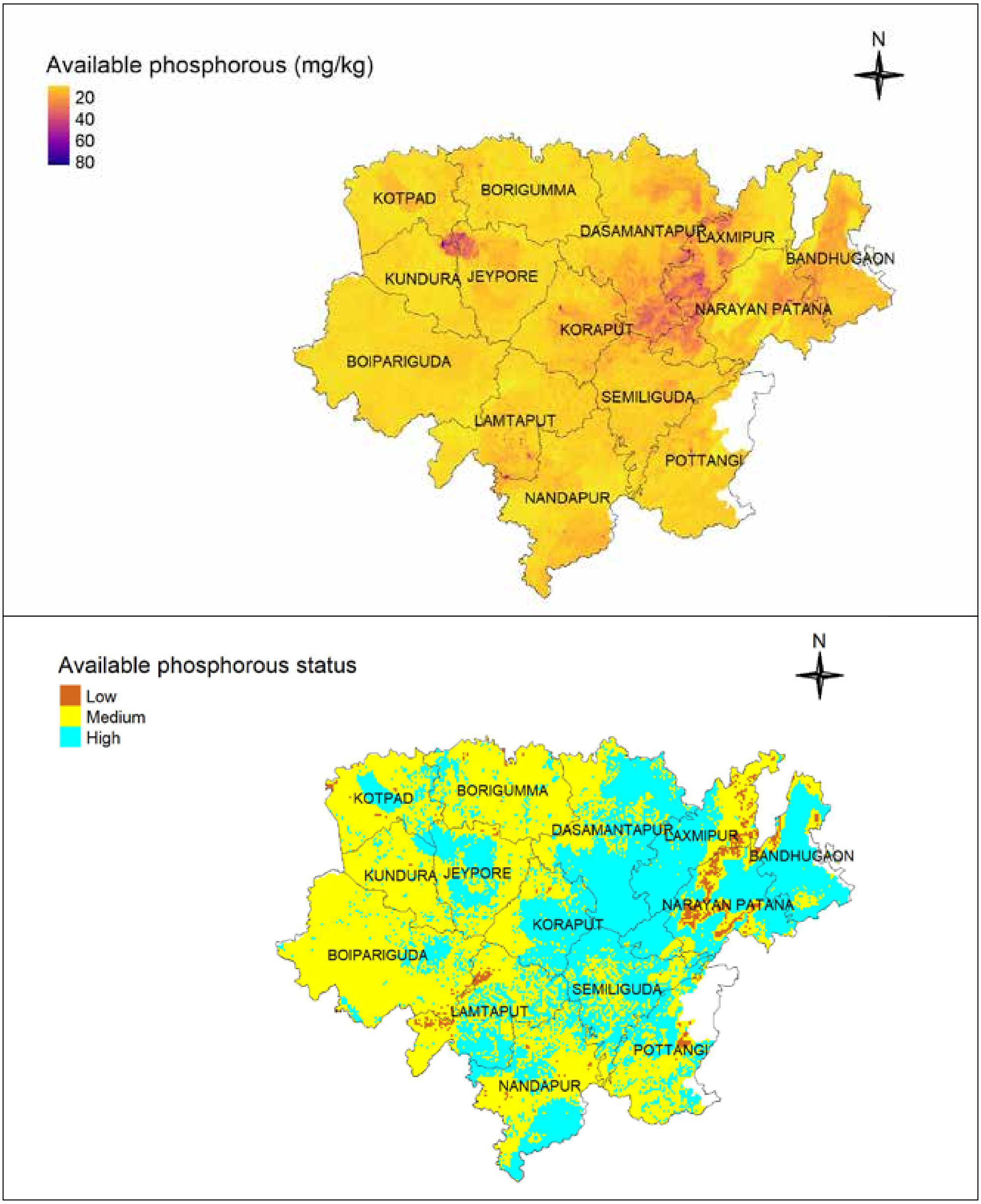


Figure 5.181. Status of available phosphorous in soils of Koraput district.

Exchangeable Potassium

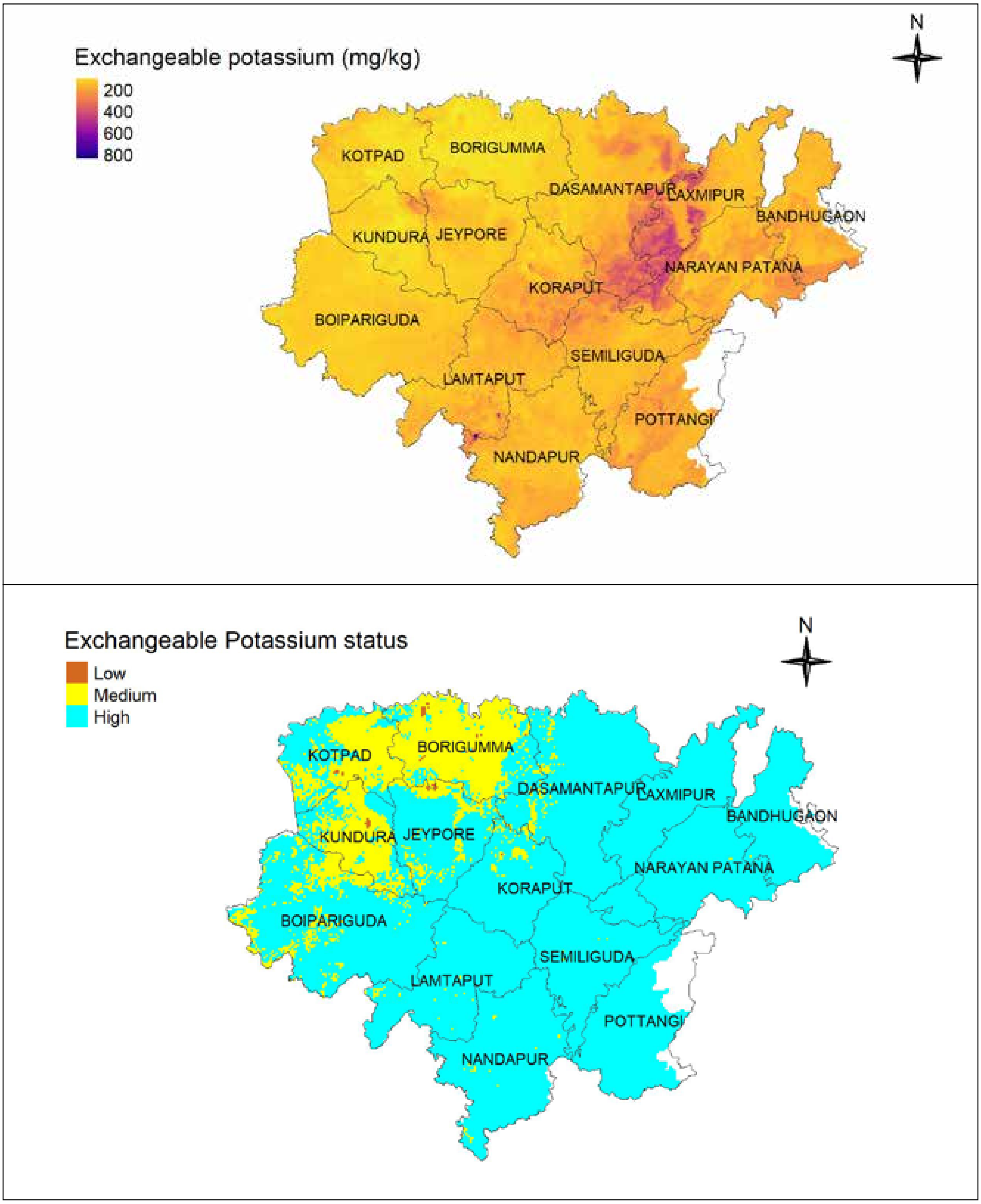


Figure 5.182. Status of exchangeable potassium in soils of Koraput district.

Available Sulfur

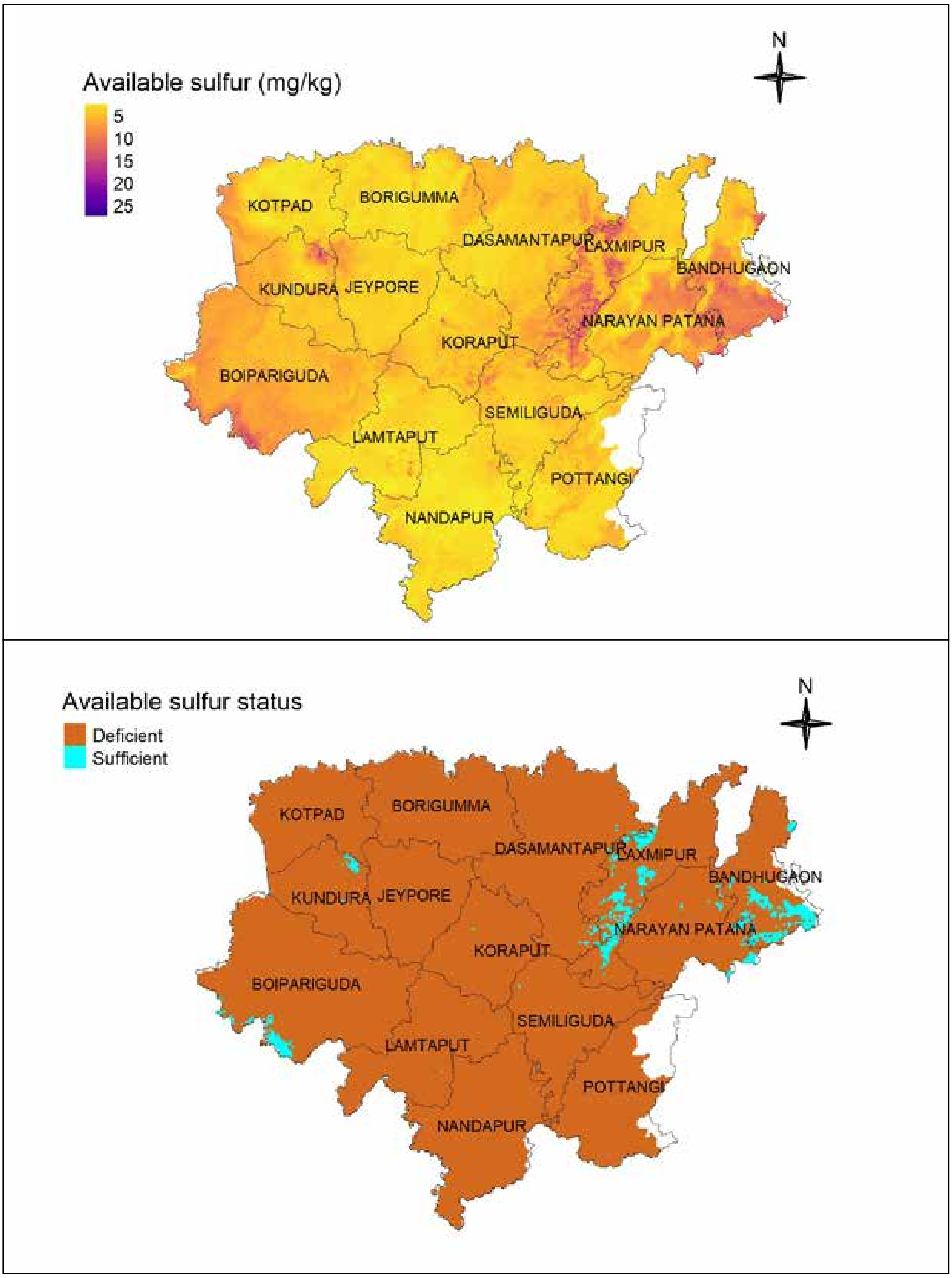


Figure 5.183. Status of available sulfur in soils of Koraput district.

Available Boron

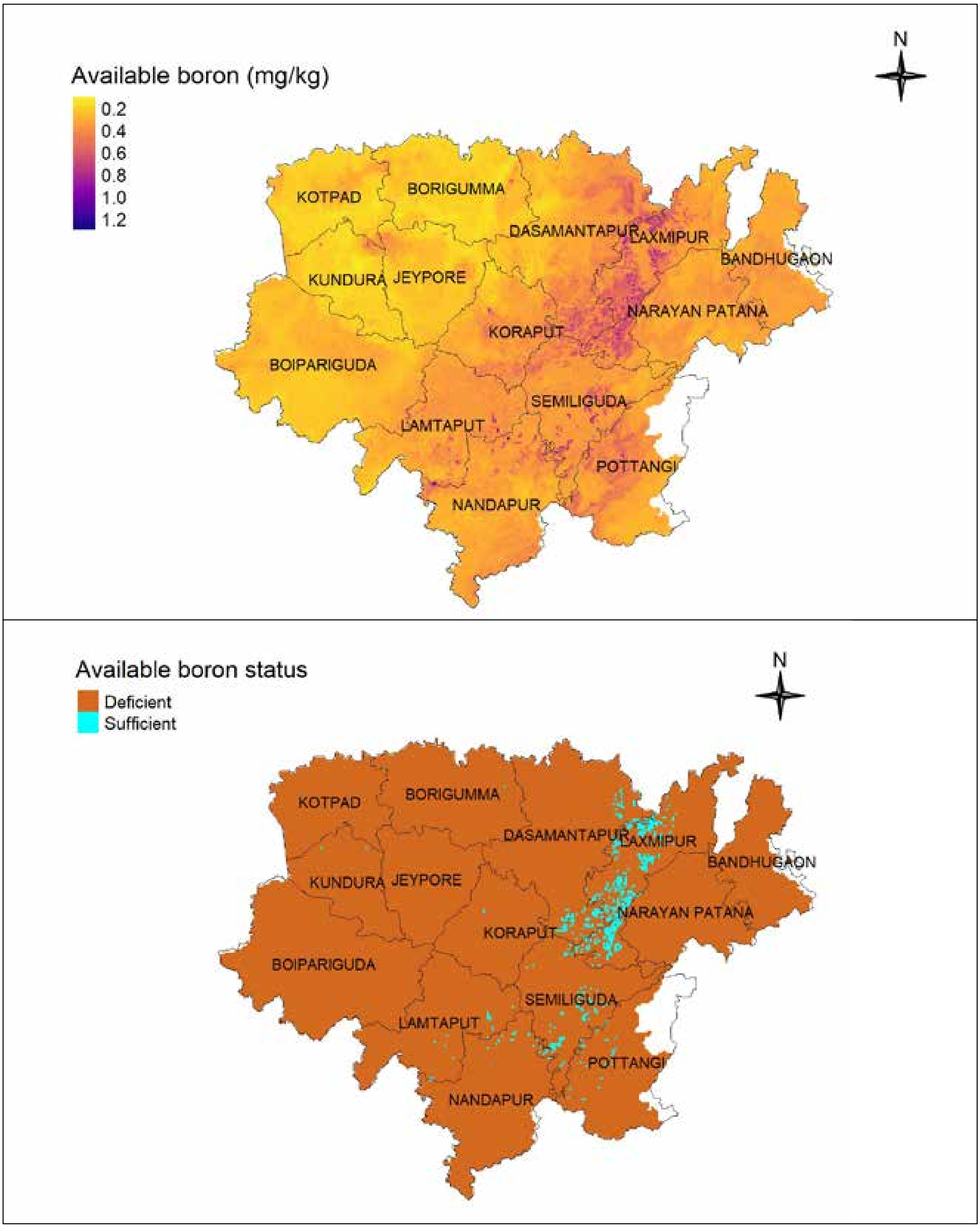


Figure 5.184. Status of available boron in soils of Koraput district.

Available Zinc

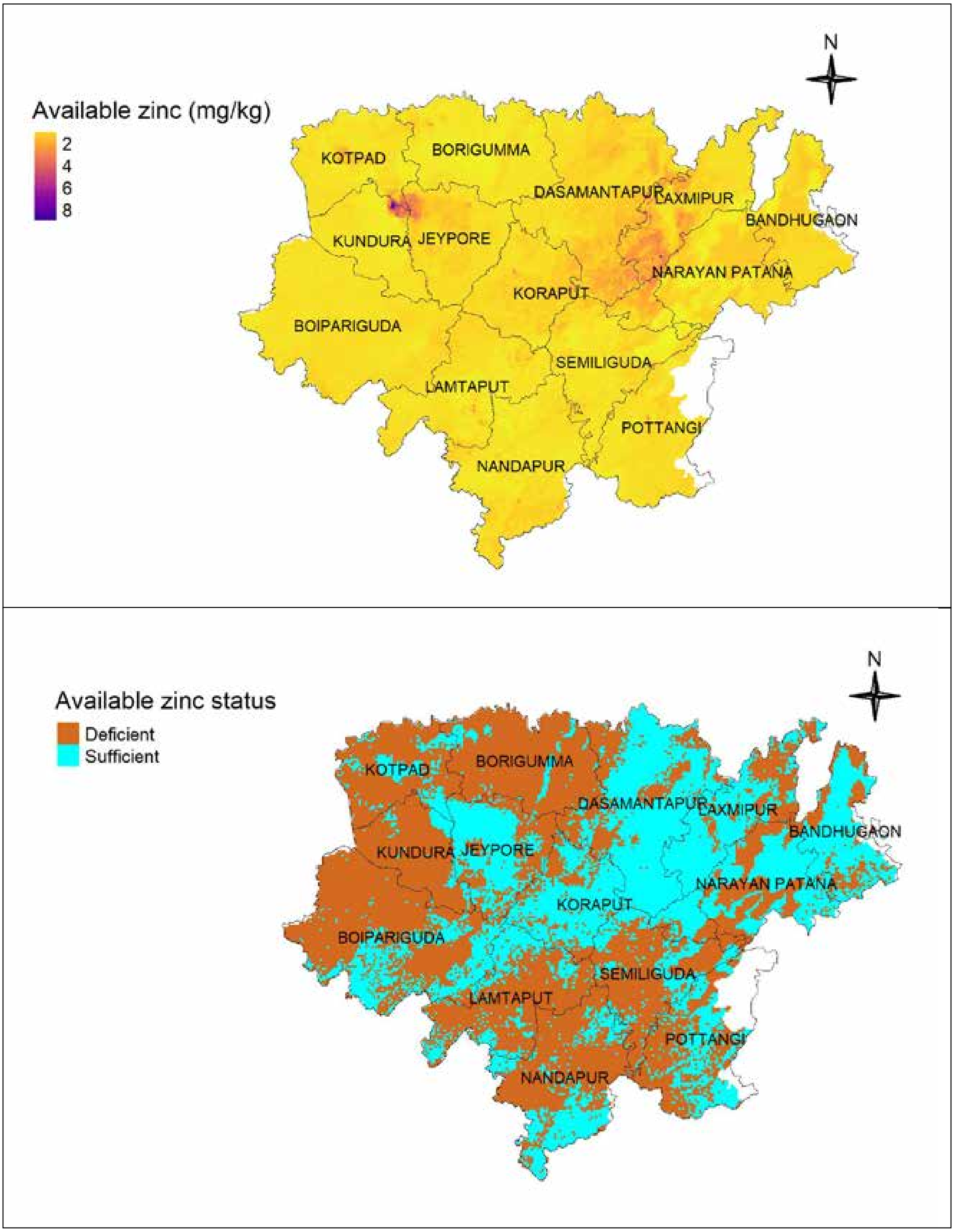


Figure 5.185. Status of available zinc in soils of Koraput district.

Malkangiri | pH

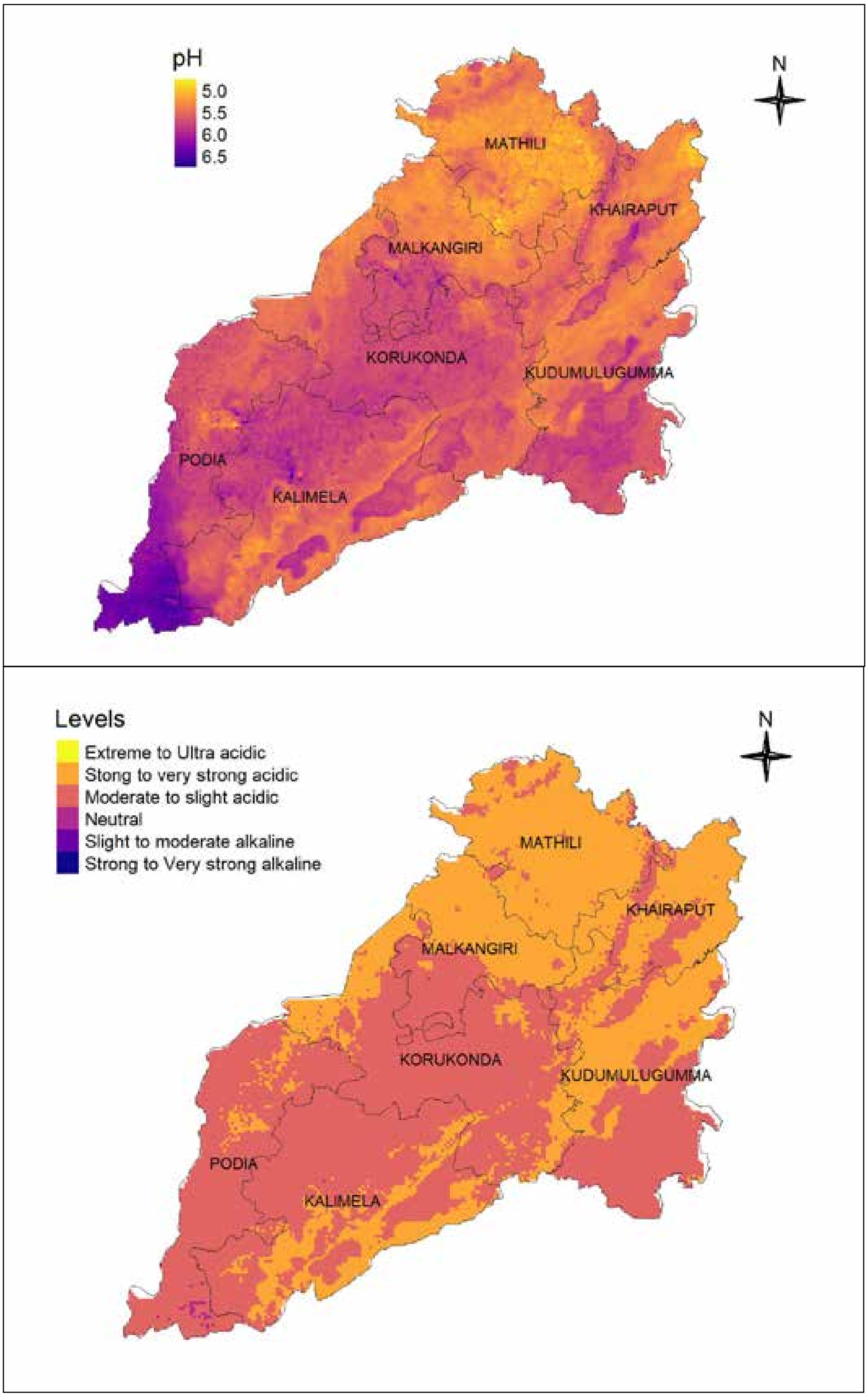


Figure 5.186. pH status in soils of Malkangiri district.

Electrical conductivity

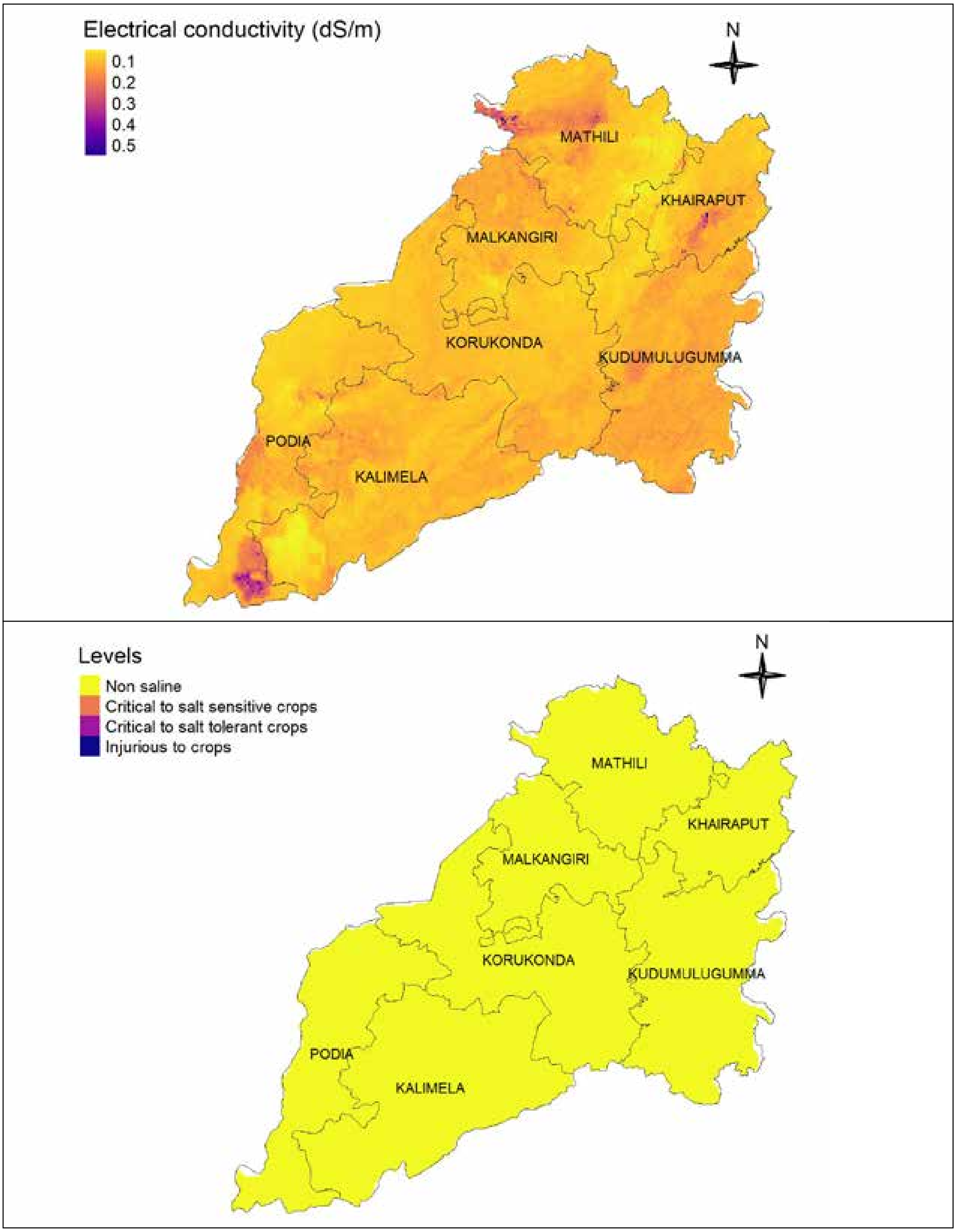


Figure 5.187. Status of electrical conductivity in soils of Malkangiri district.

Organic carbon

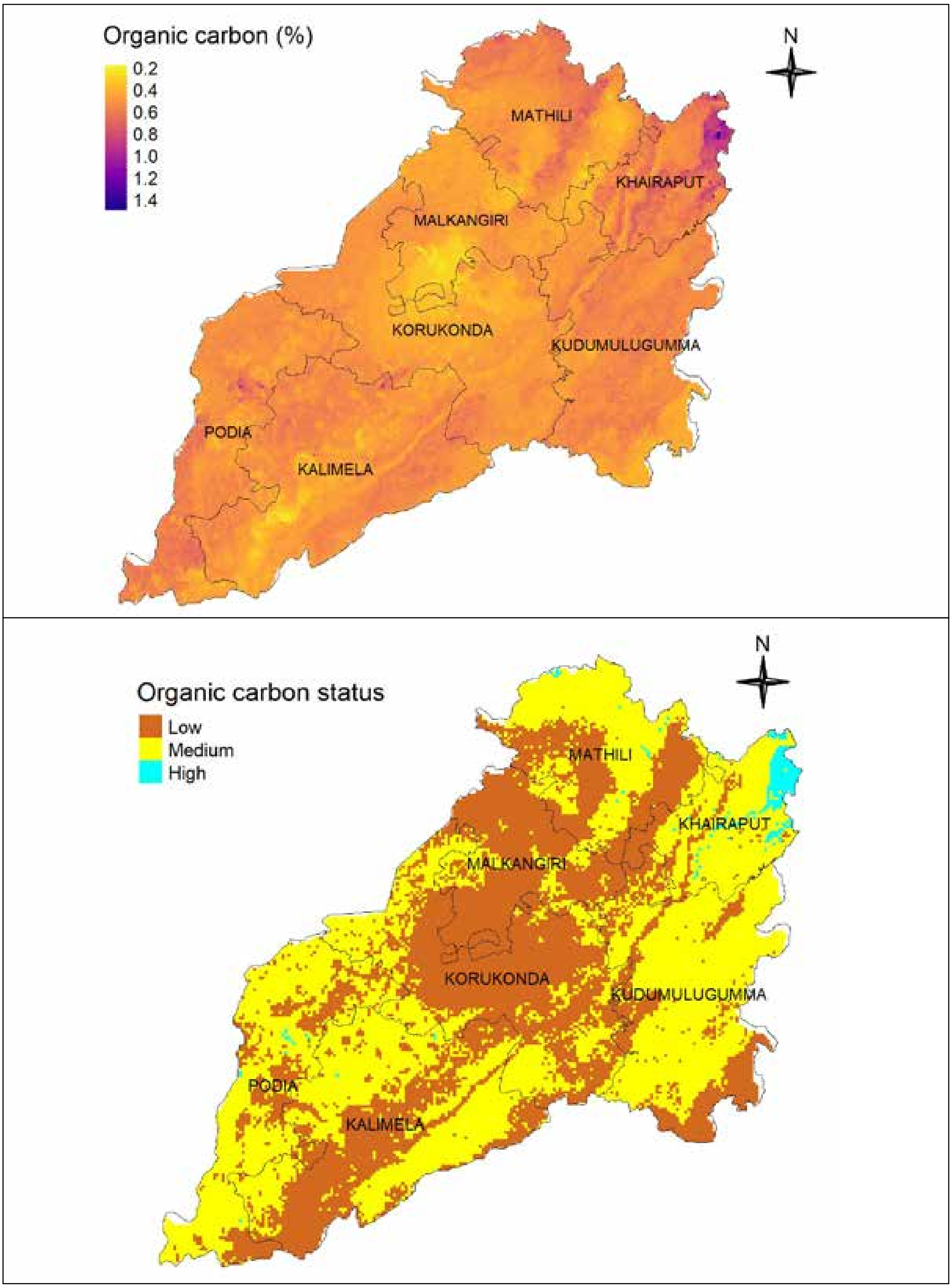


Figure 5.188. Organic carbon status in soils of Malkangiri district.

Available Phosphorous

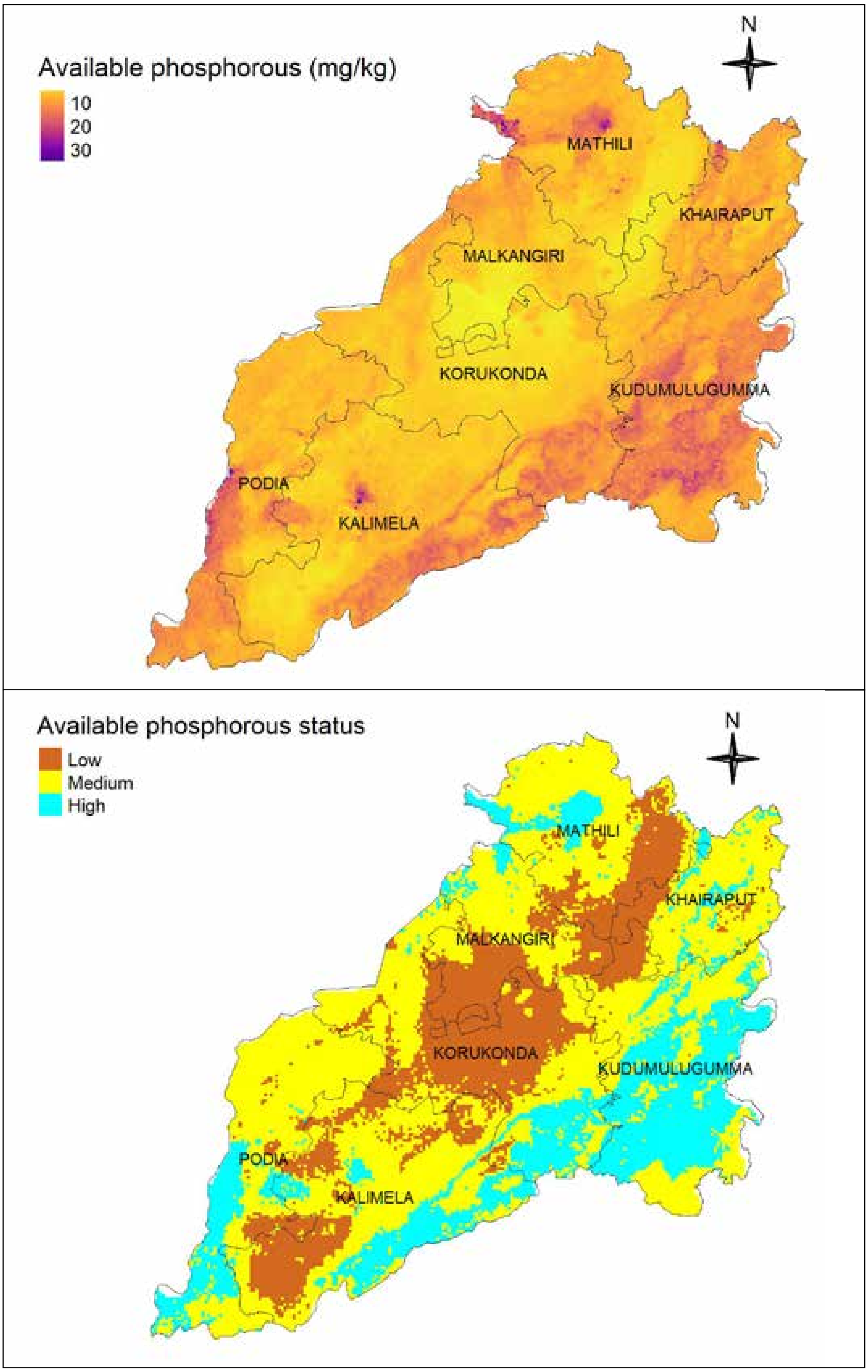


Figure 5.189. Status of available phosphorous in soils of Malkangiri district.

Exchangeable Potassium

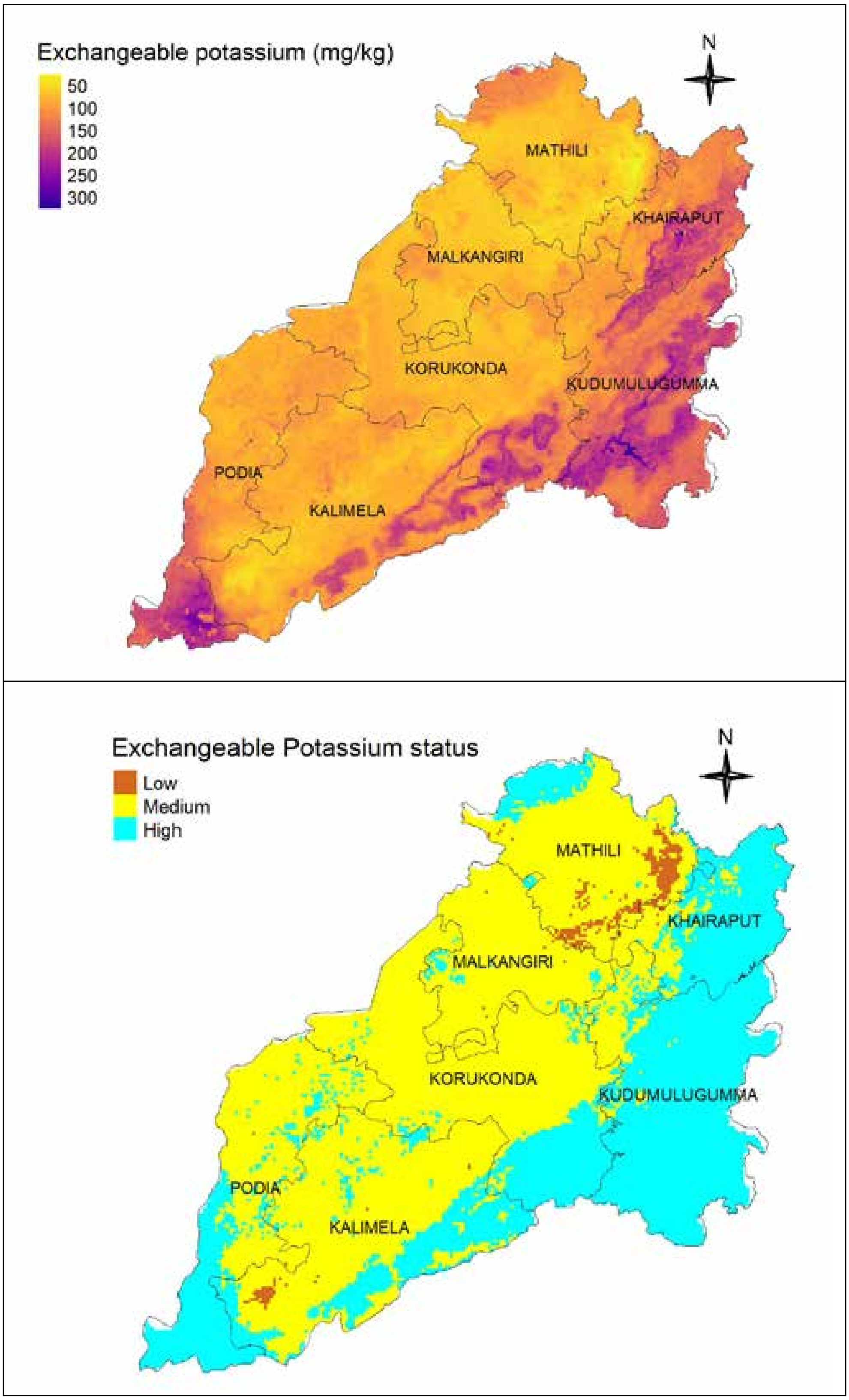


Figure 5.190. Status of exchangeable potassium in soils of Malkangiri district.

Available Sulfur

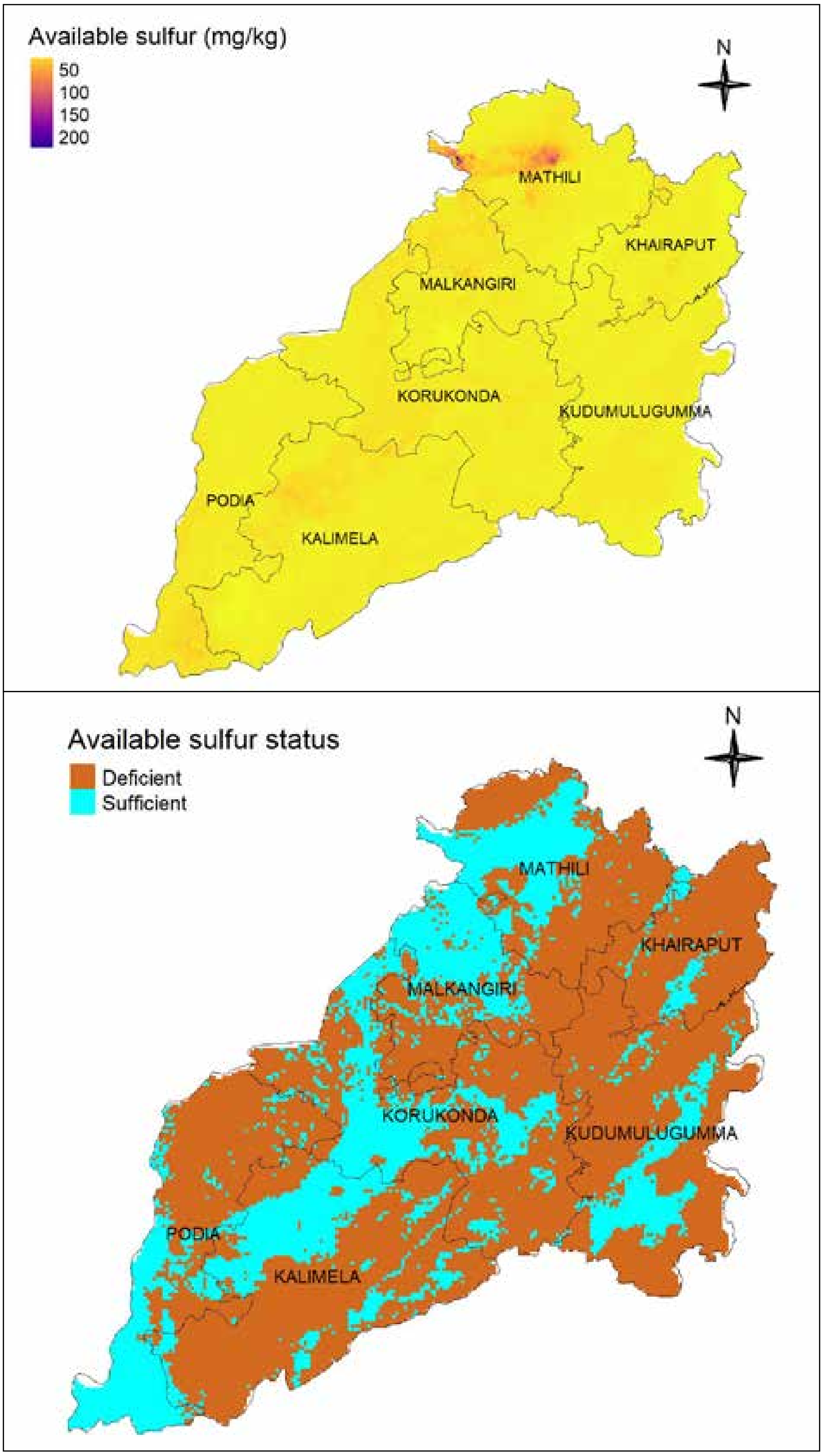


Figure 5.191. Status of available sulfur in soils of Malkangiri district.

Available Boron

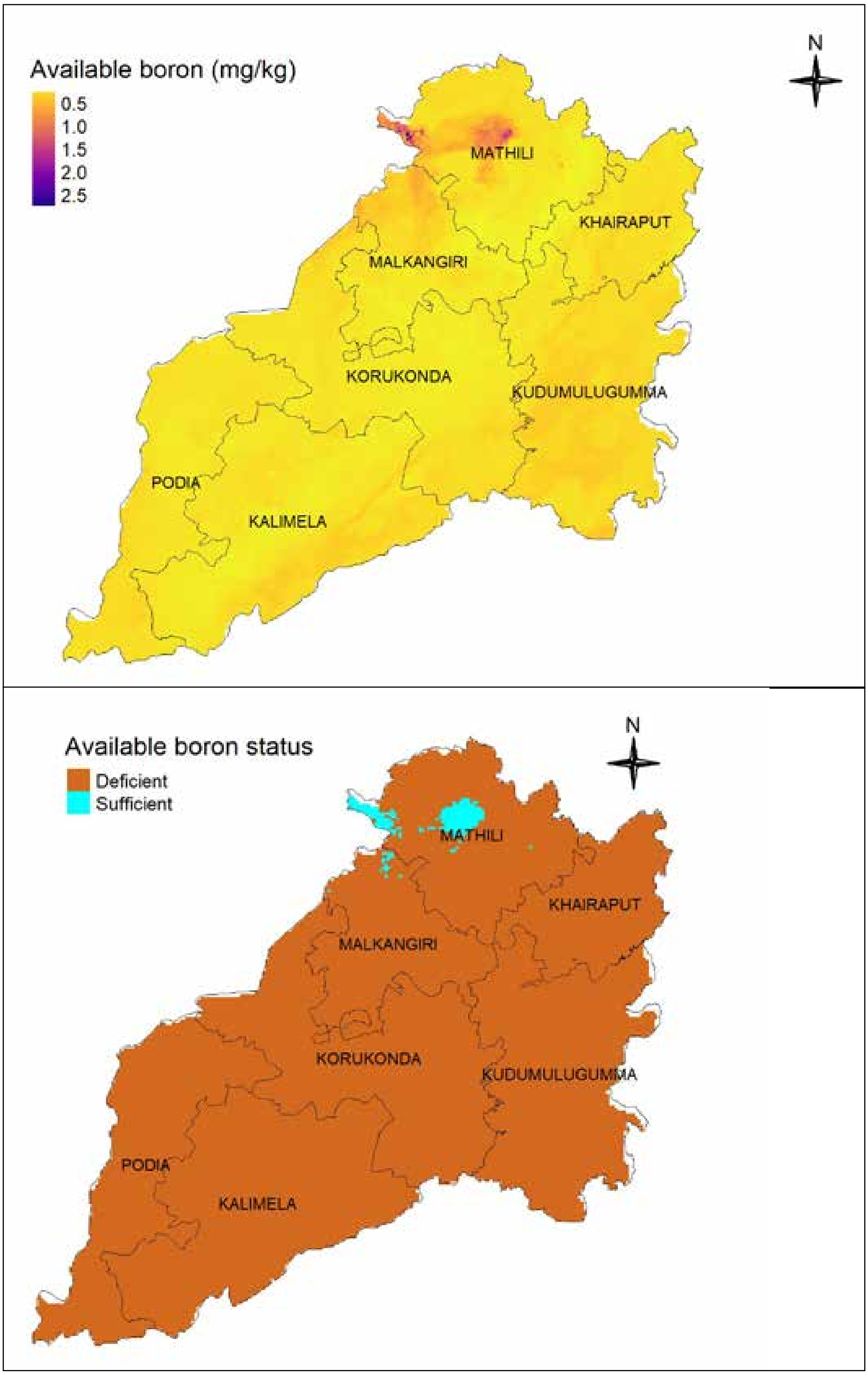


Figure 5.192. Status of available boron in soils of Malkangiri district.

Available Zinc

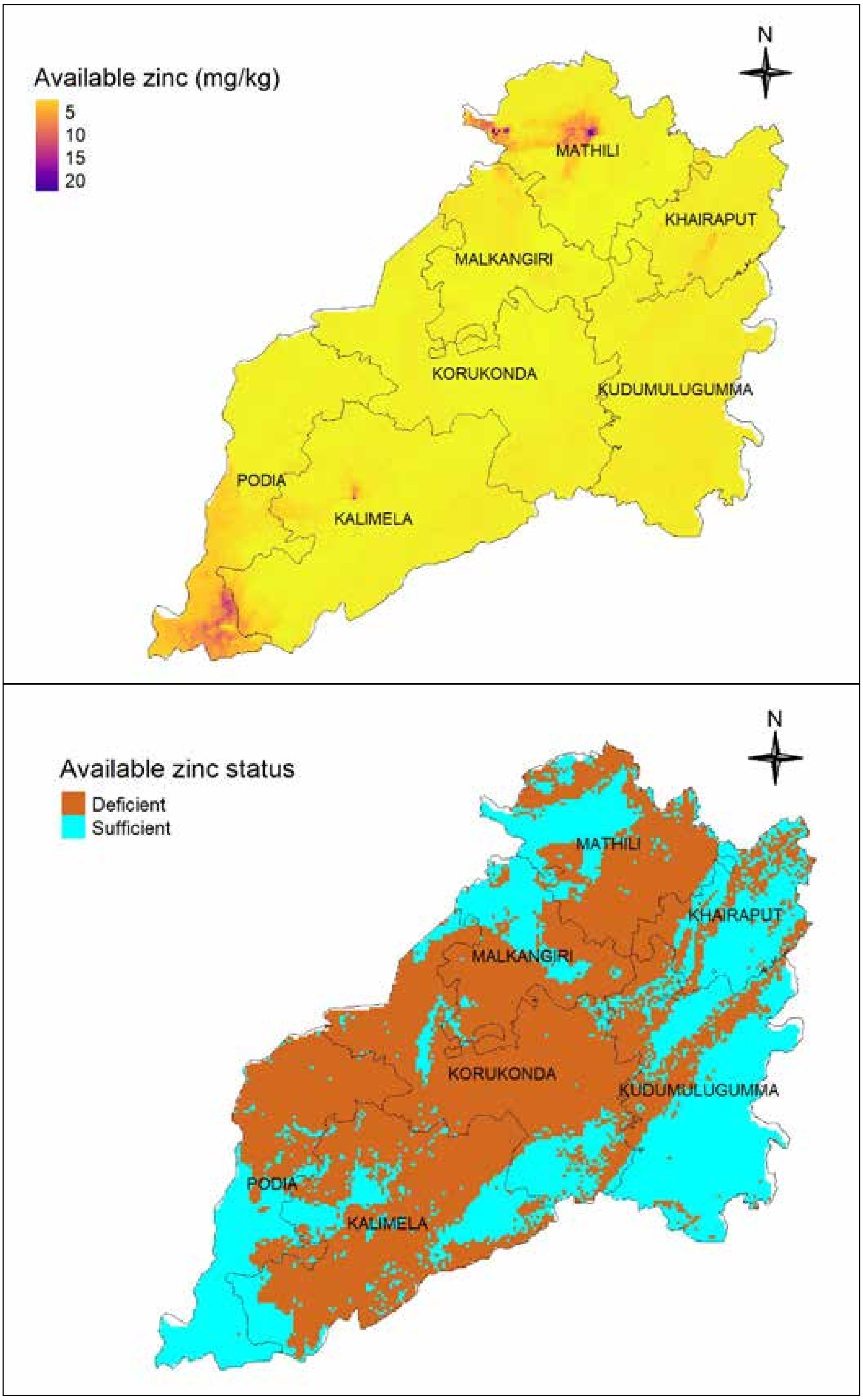


Figure 5.193. Status of available zinc in soils of Malkangiri district.

Mayurbhanj | pH

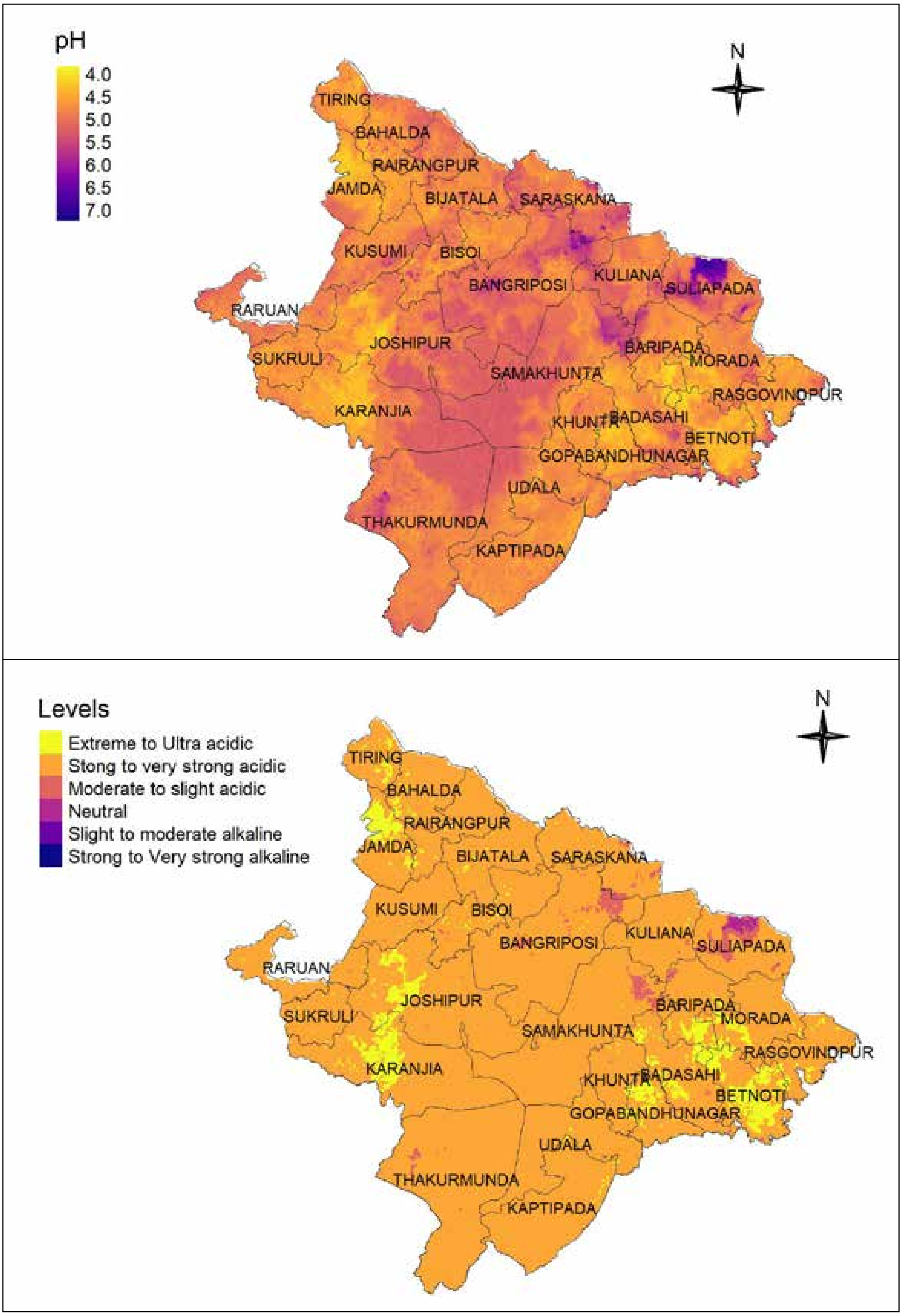


Figure 5.194. pH status in soils of Mayurbhanj district.

Electrical conductivity

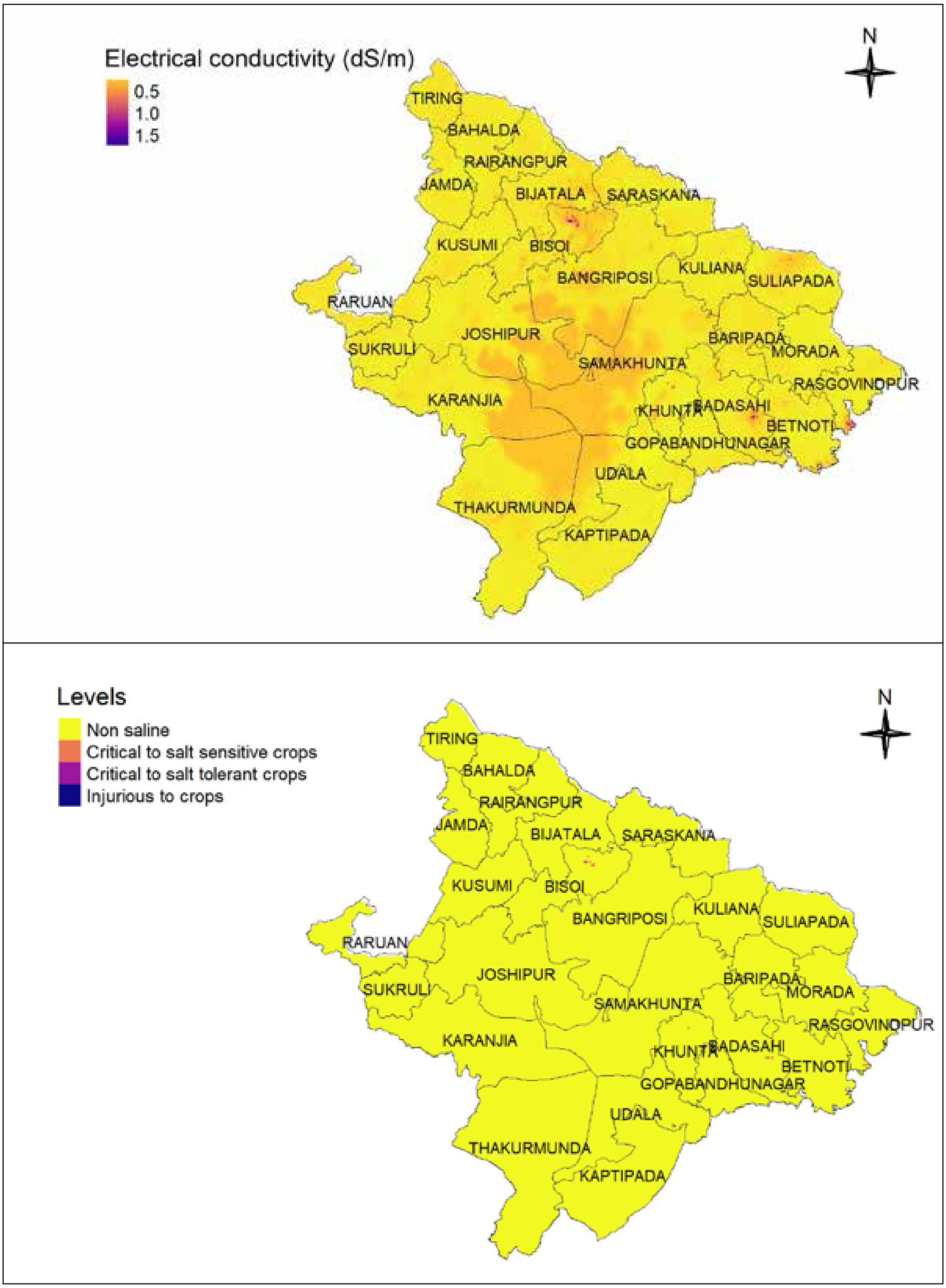


Figure 5.195. Status of electrical conductivity in soils of Mayurbhanj district.

Organic carbon

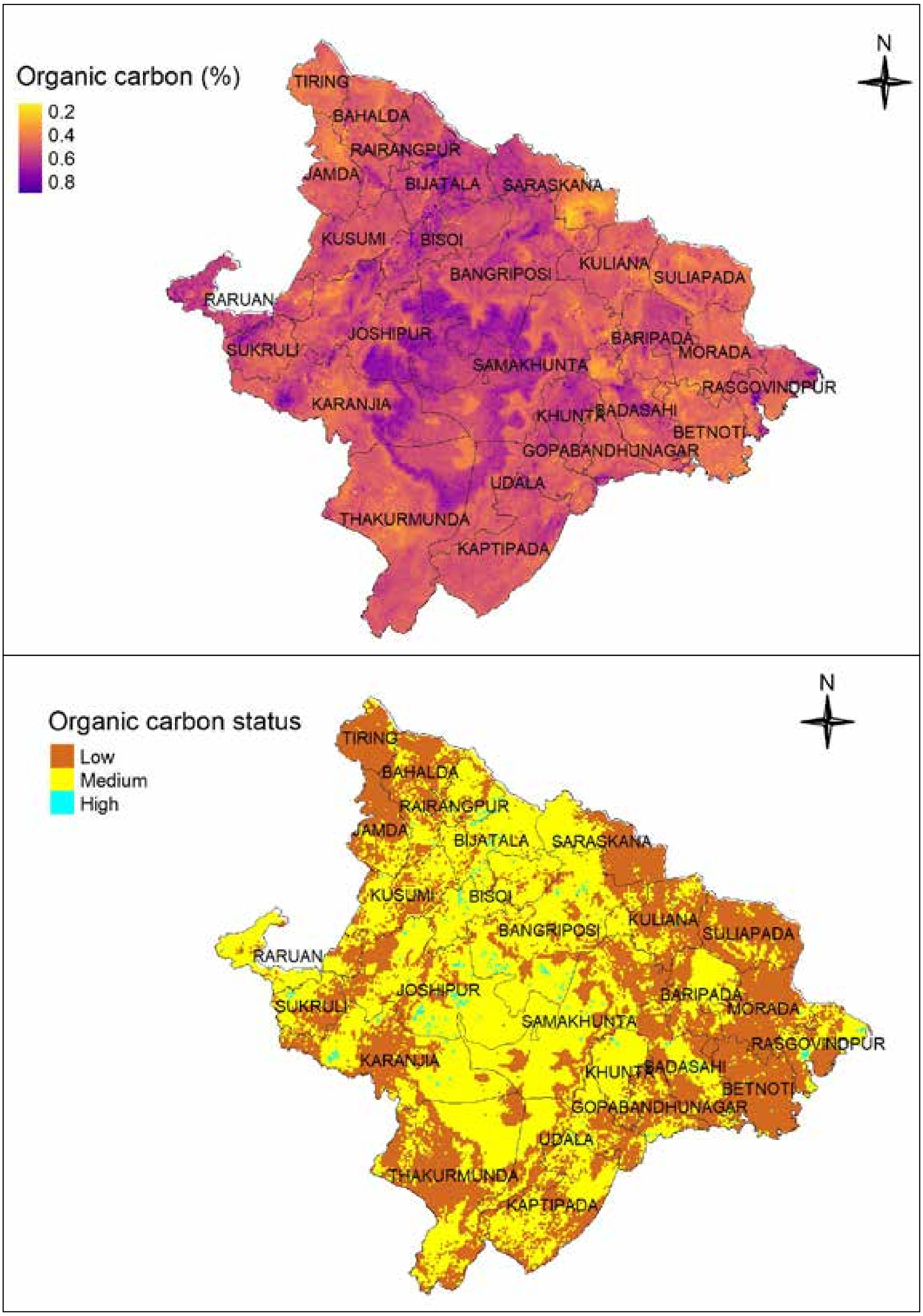


Figure 5.196. Organic carbon status in soils of Mayurbhanj district.

Available Phosphorous

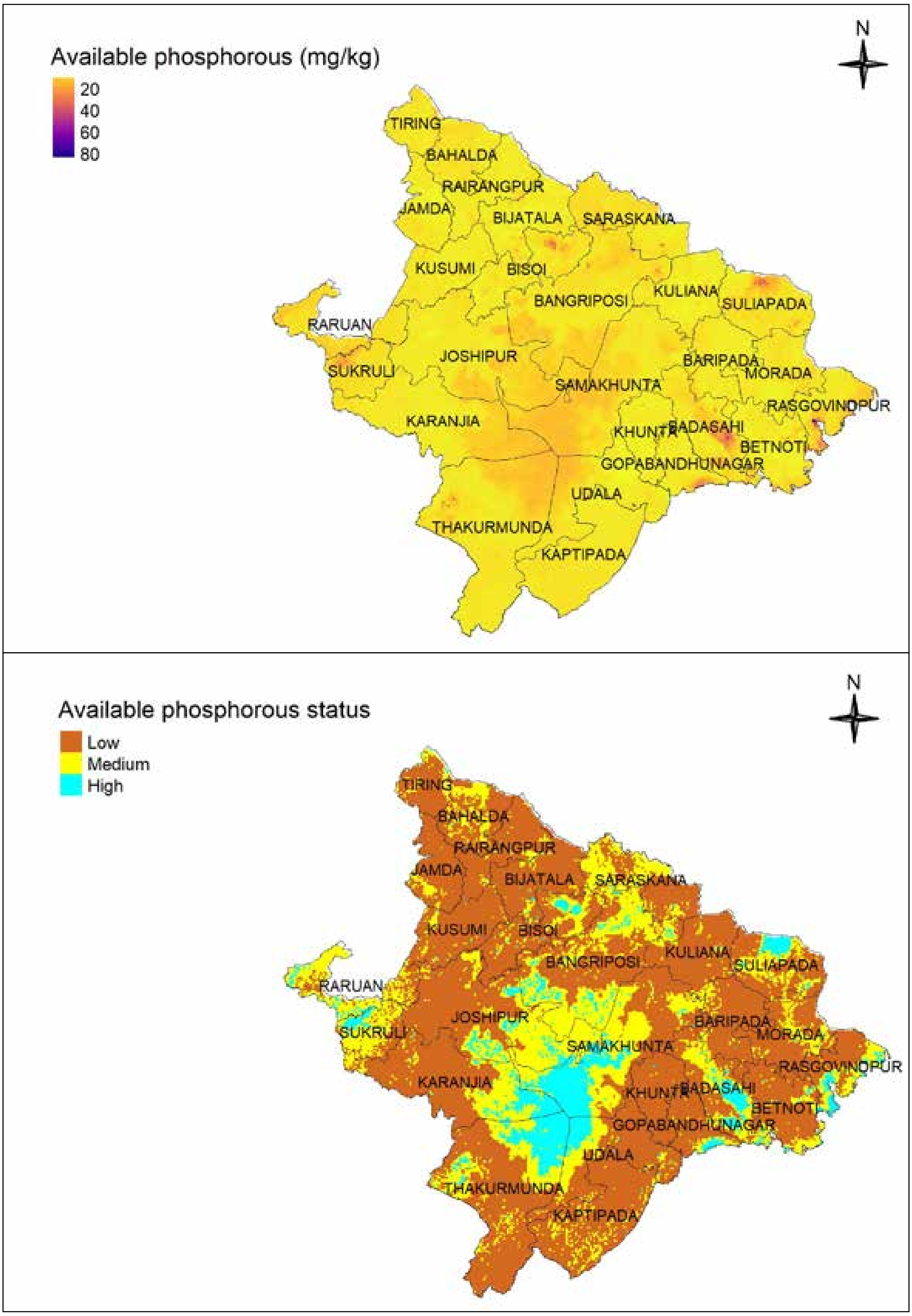


Figure 5.197. Status of available phosphorous in soils of Mayurbhanj district.

Exchangeable Potassium

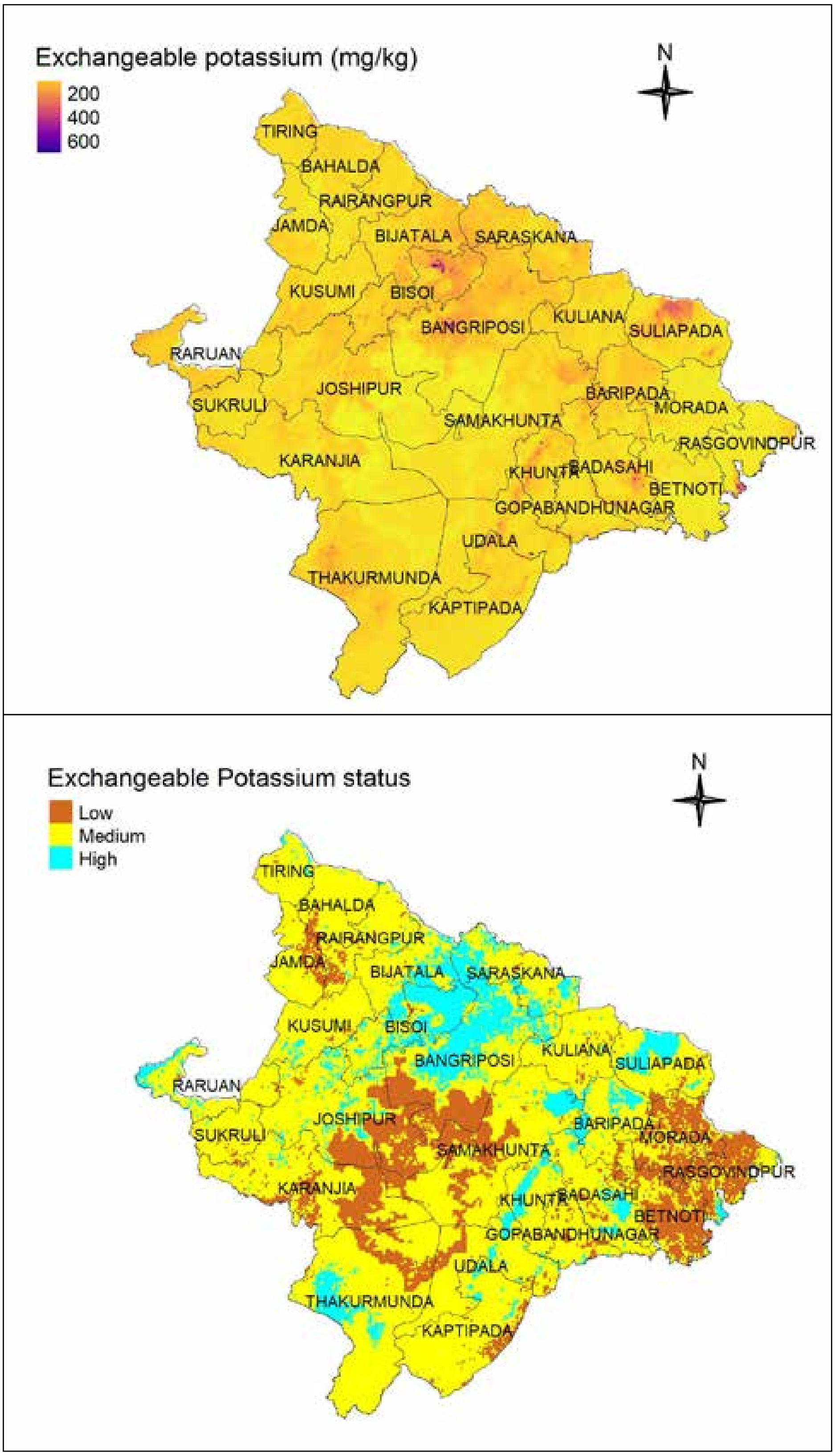


Figure 5.198. Status of exchangeable potassium in soils of Mayurbhanj district.

Available Sulfur

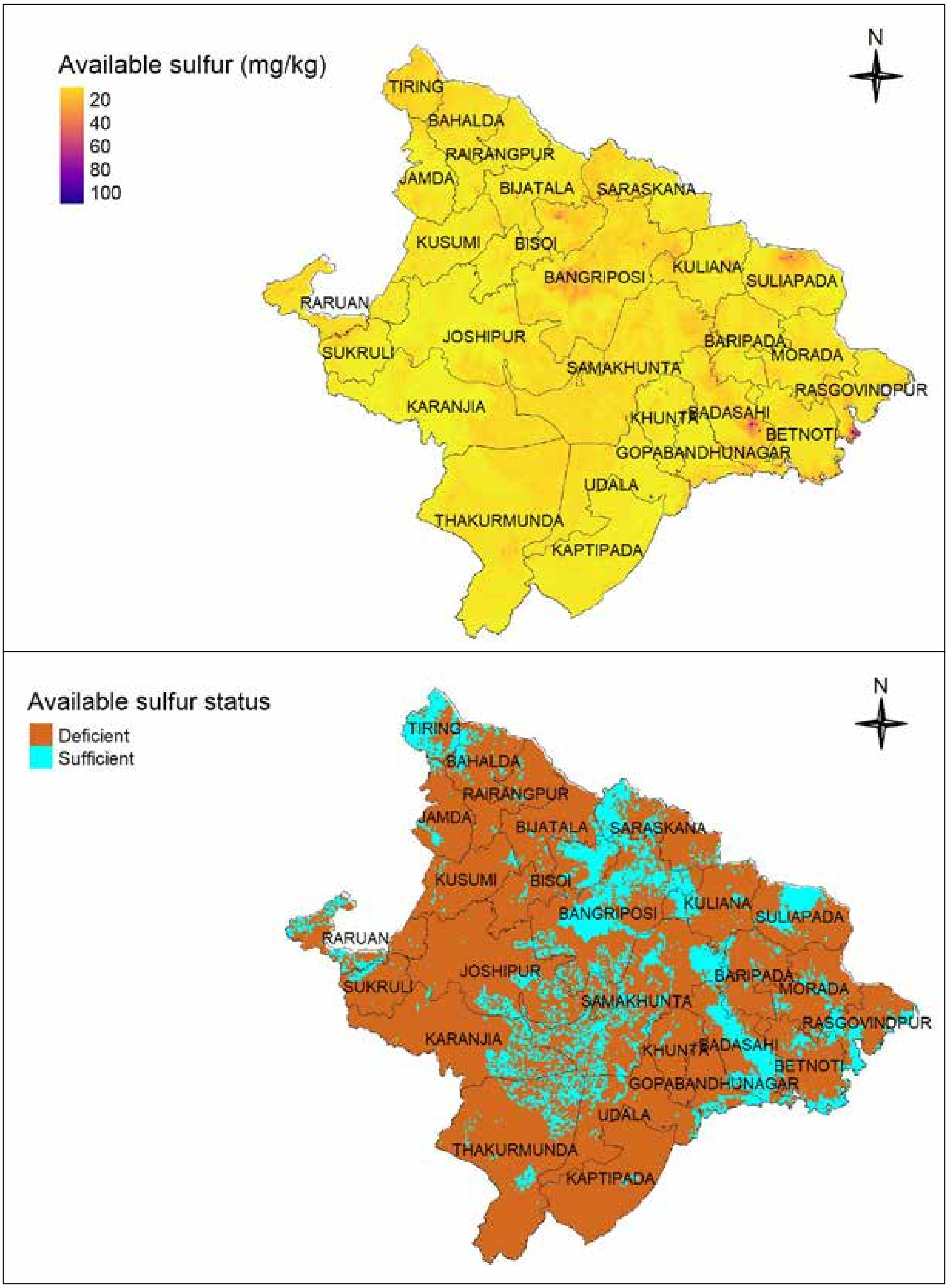


Figure 5.199. Status of available sulfur in soils of Mayurbhanj district.

Available Boron

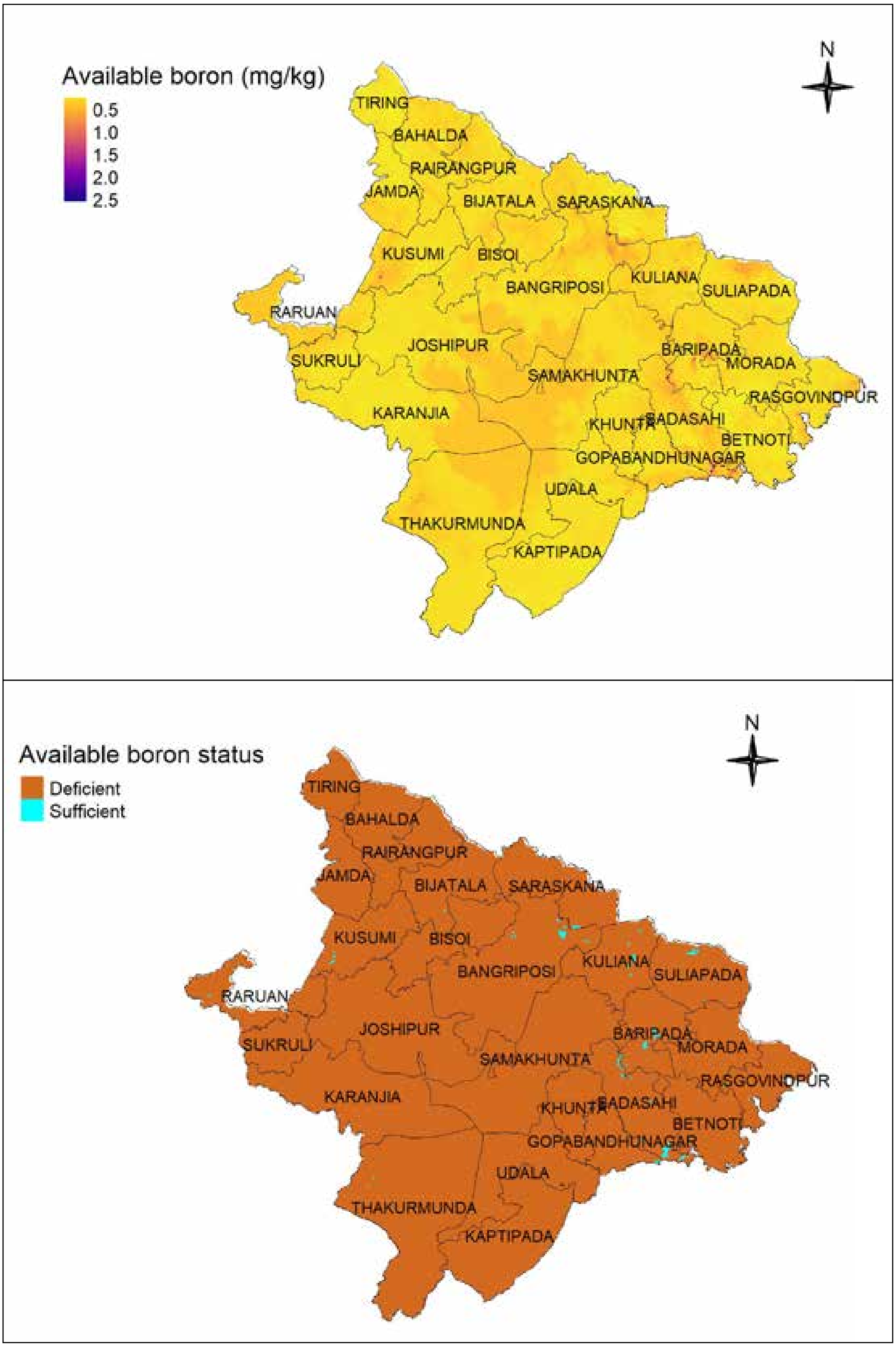


Figure 5.200. Status of available boron in soils of Mayurbhanj district.

Available Zinc

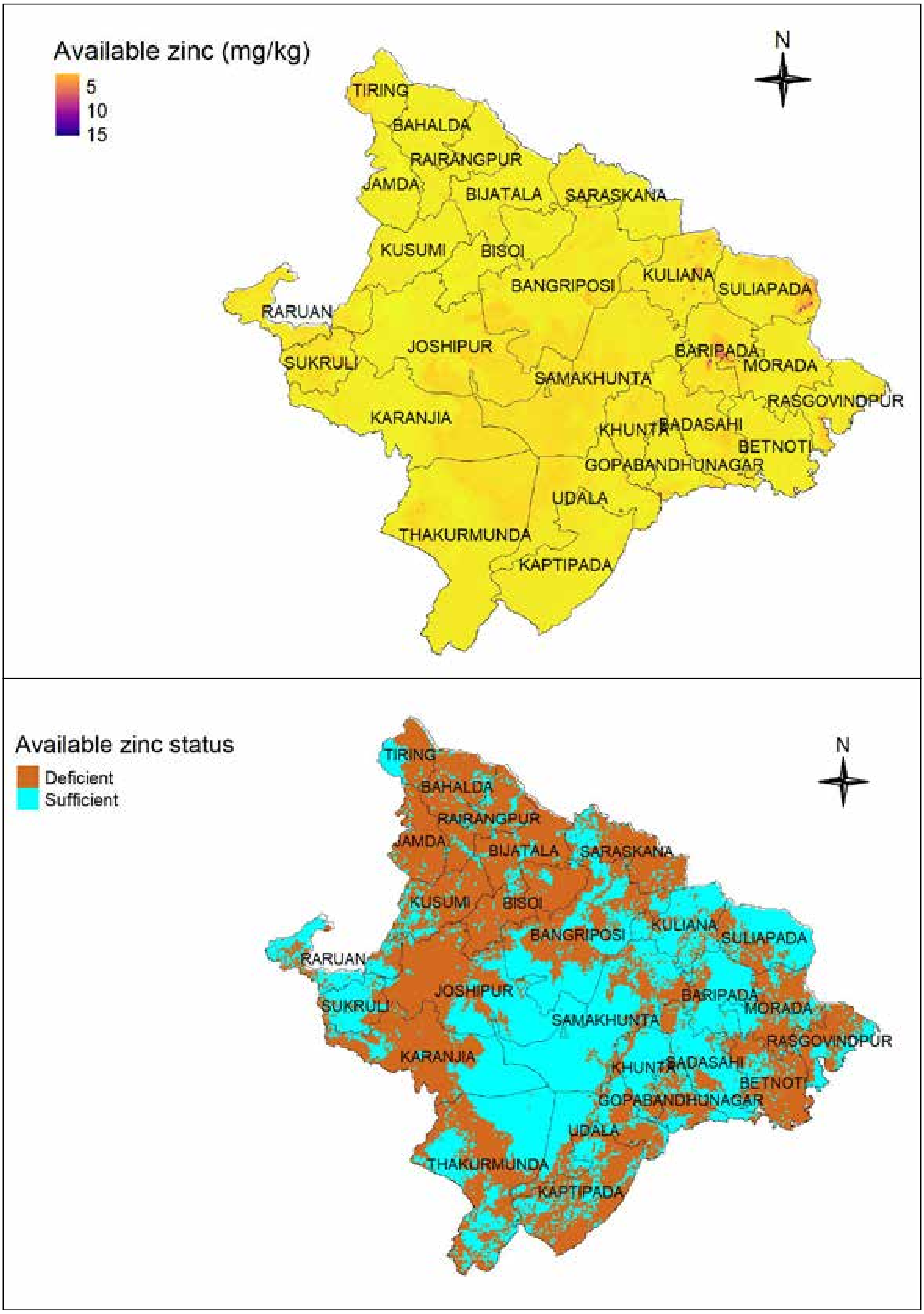


Figure 5.201. Status of available zinc in soils of Mayurbhanj district.

Nabarangpur | pH

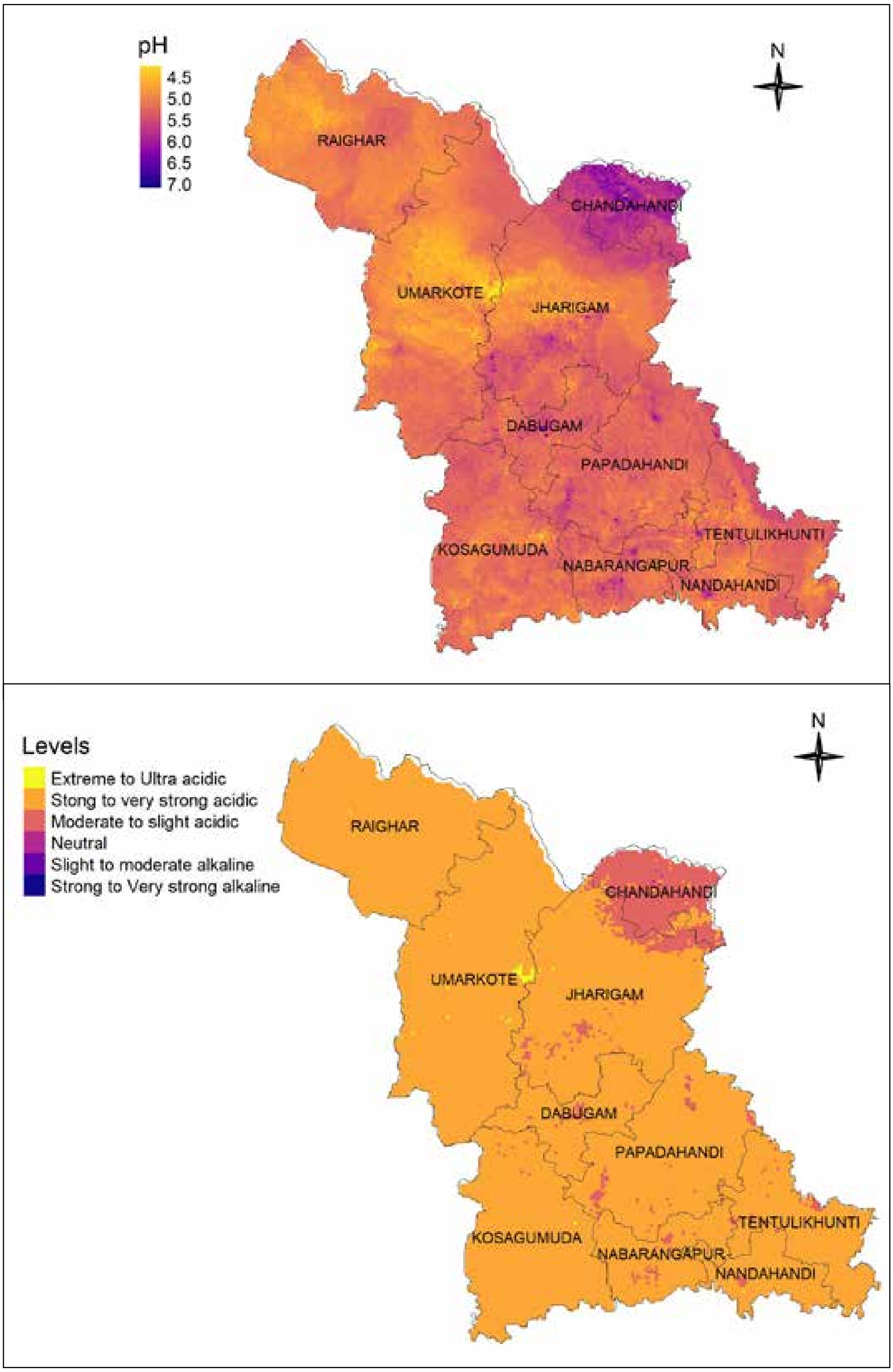


Figure 5.202. pH status in soils of Nabarangpur district.

Electrical conductivity

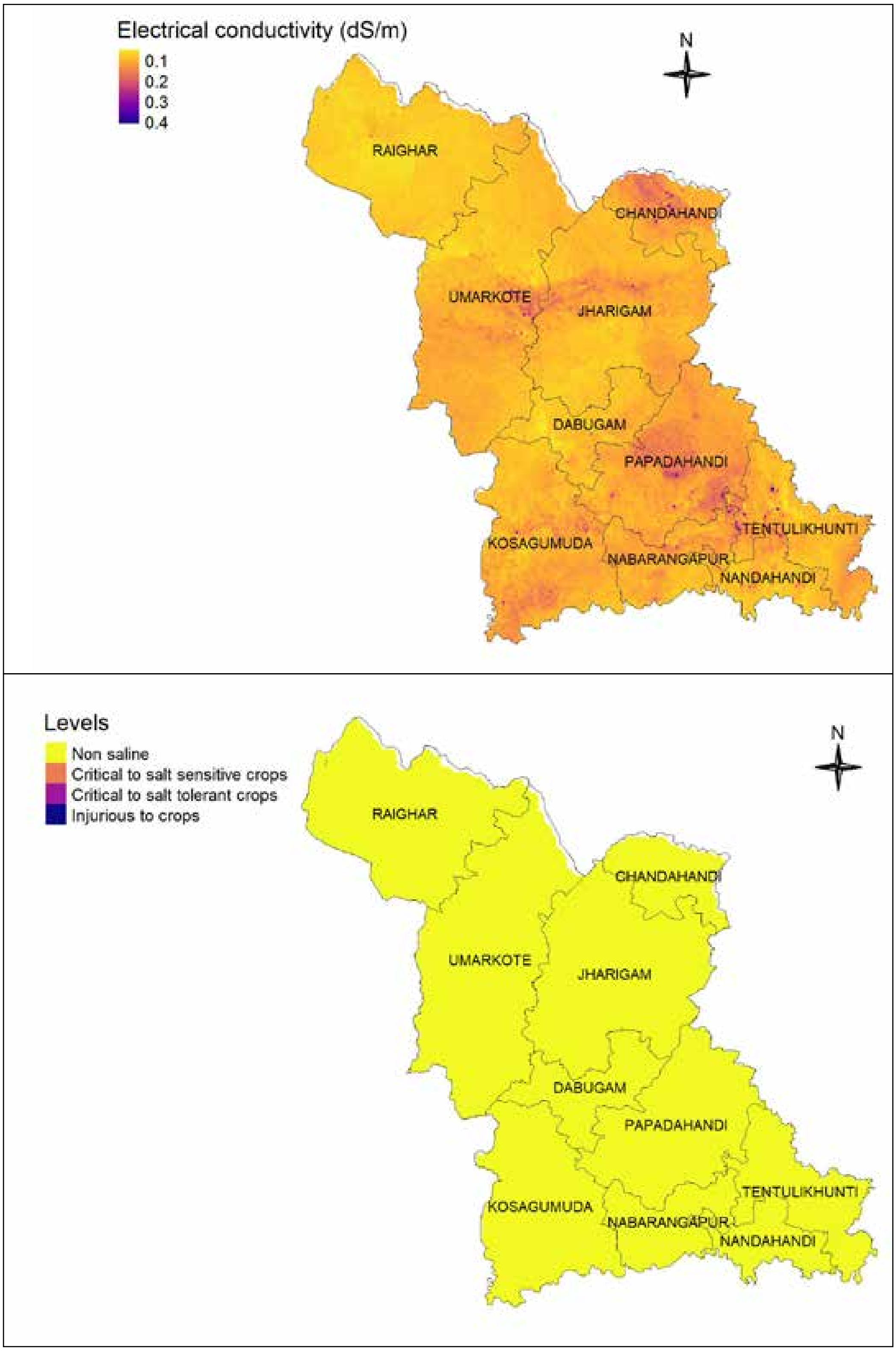


Figure 5.203. Status of electrical conductivity in soils of Nabarangpur district.

Organic carbon

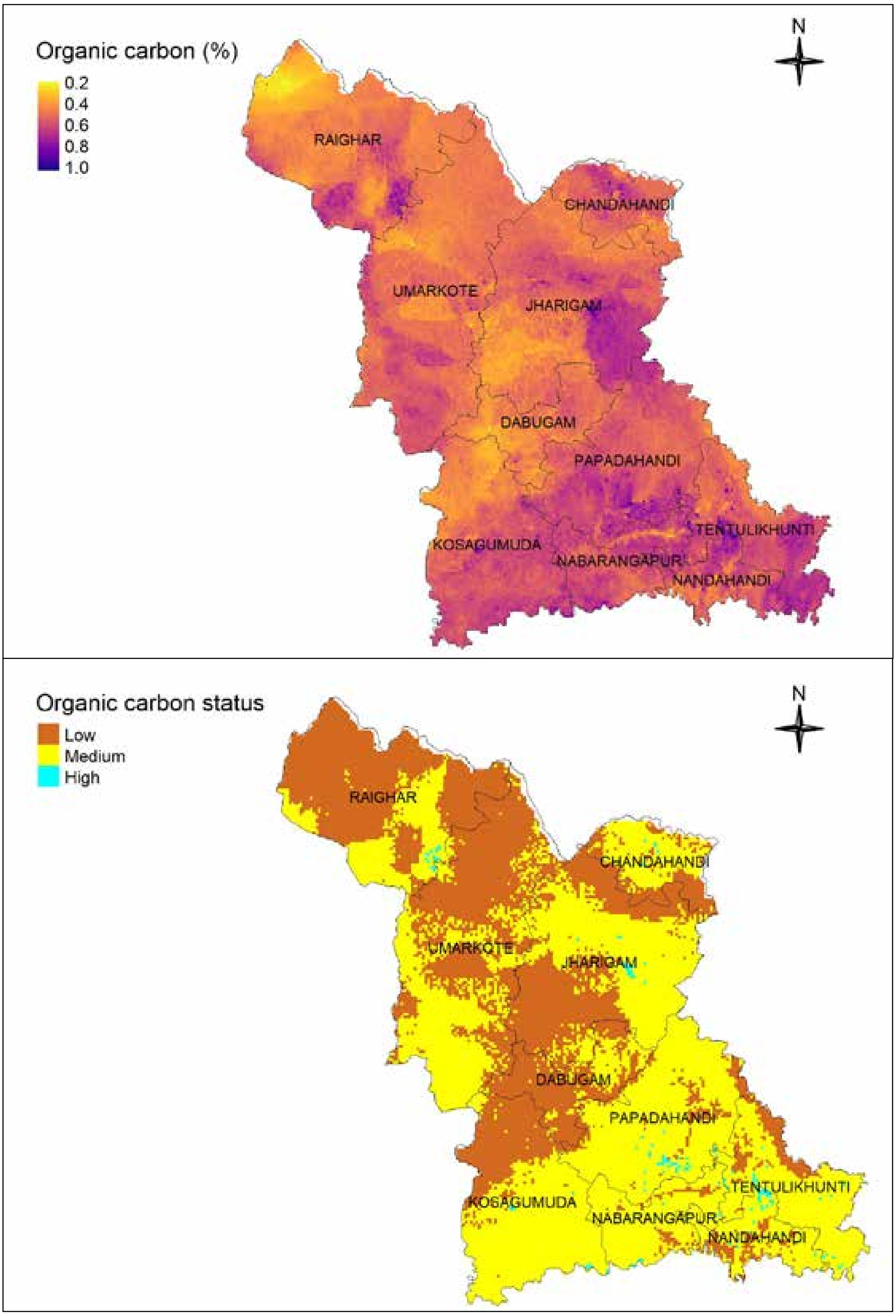


Figure 5.204. Organic carbon status in soils of Nabarangpur district.

Available Phosphorous

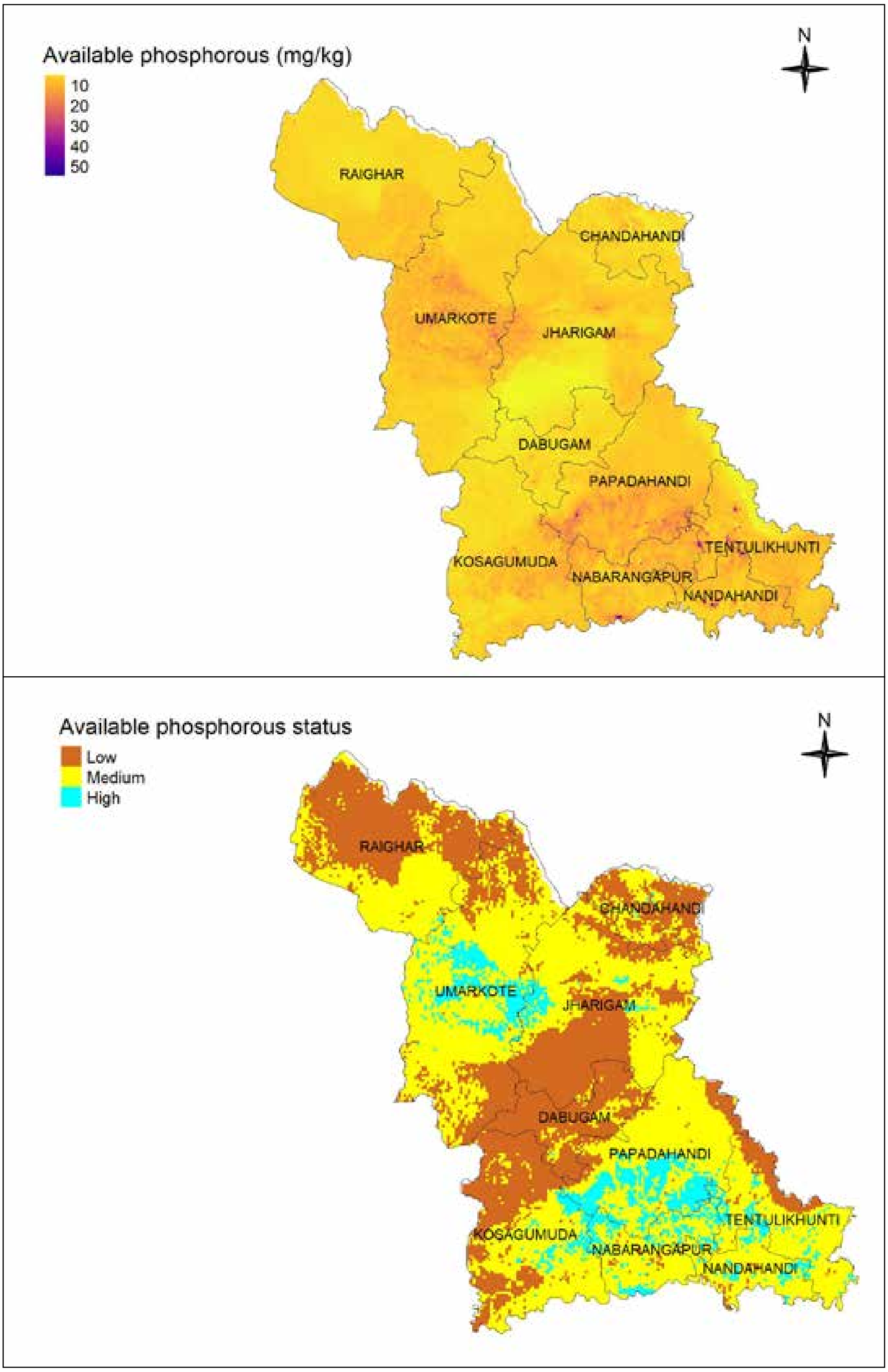


Figure 5.205. Status of available phosphorous in soils of Nabarangpur district.

Exchangeable Potassium

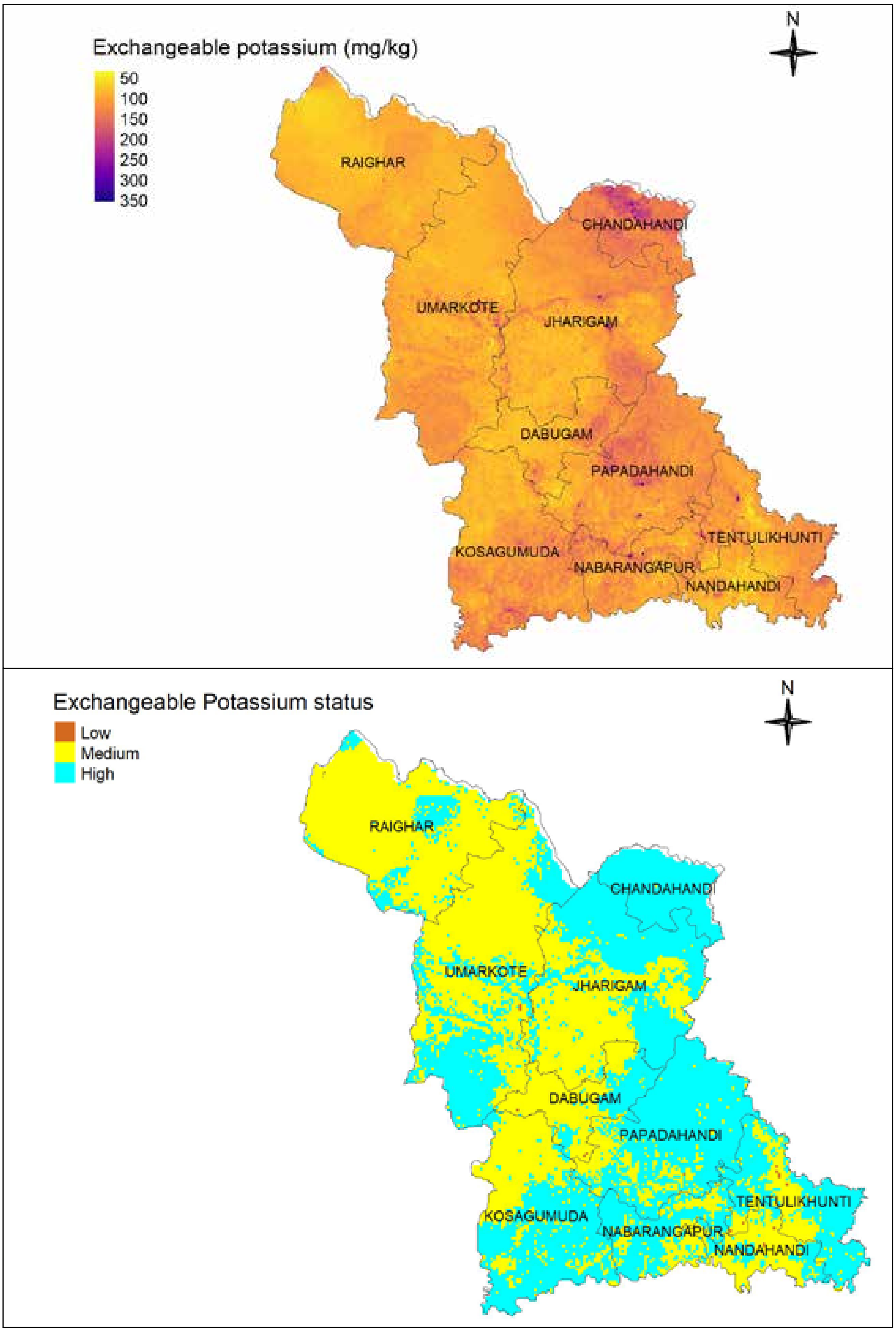


Figure 5.206. Status of exchangeable potassium in soils of Nabarangpur district.

Available Sulfur

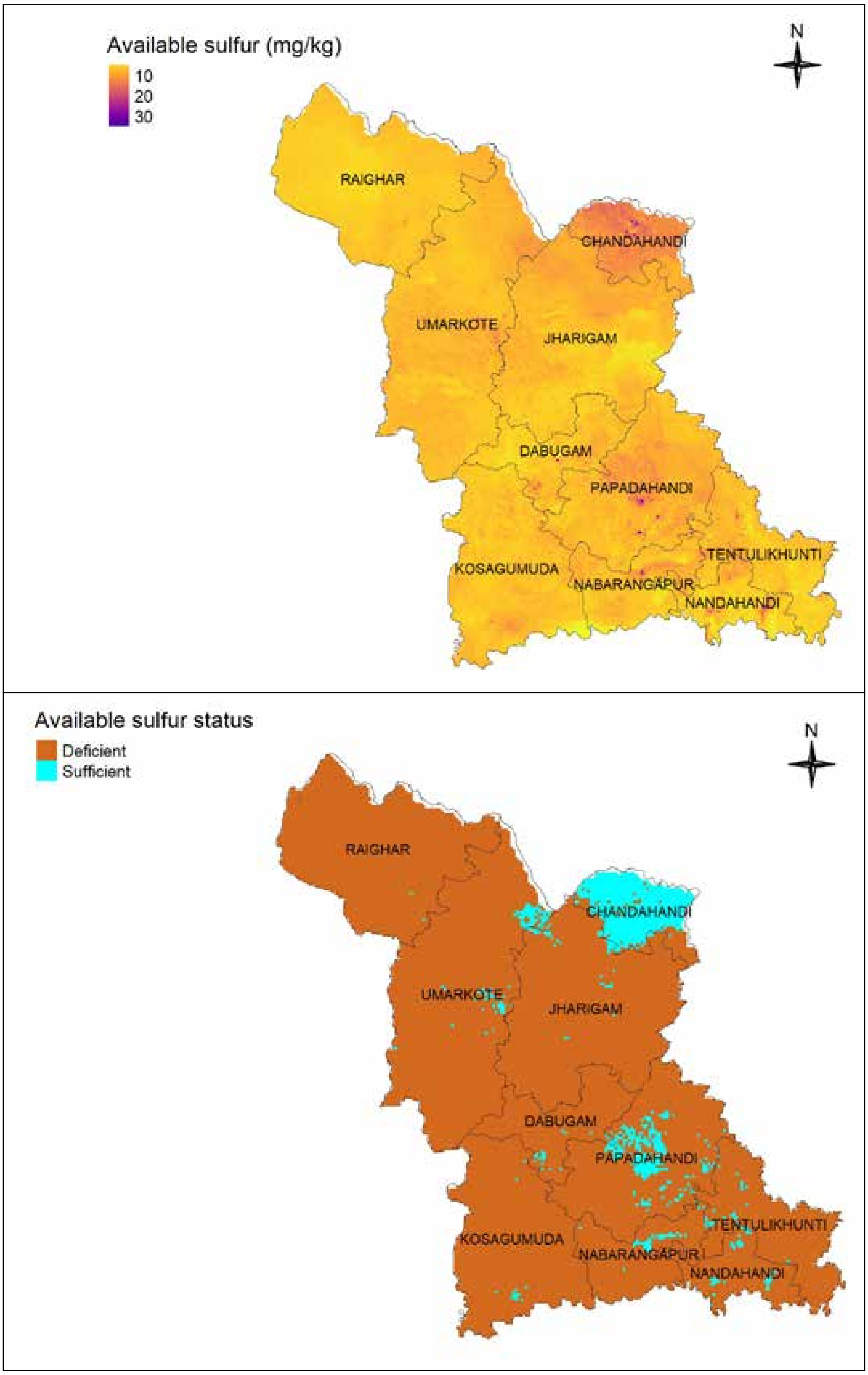


Figure 5.207. Status of available sulfur in soils of Nabarangpur district.

Available Boron

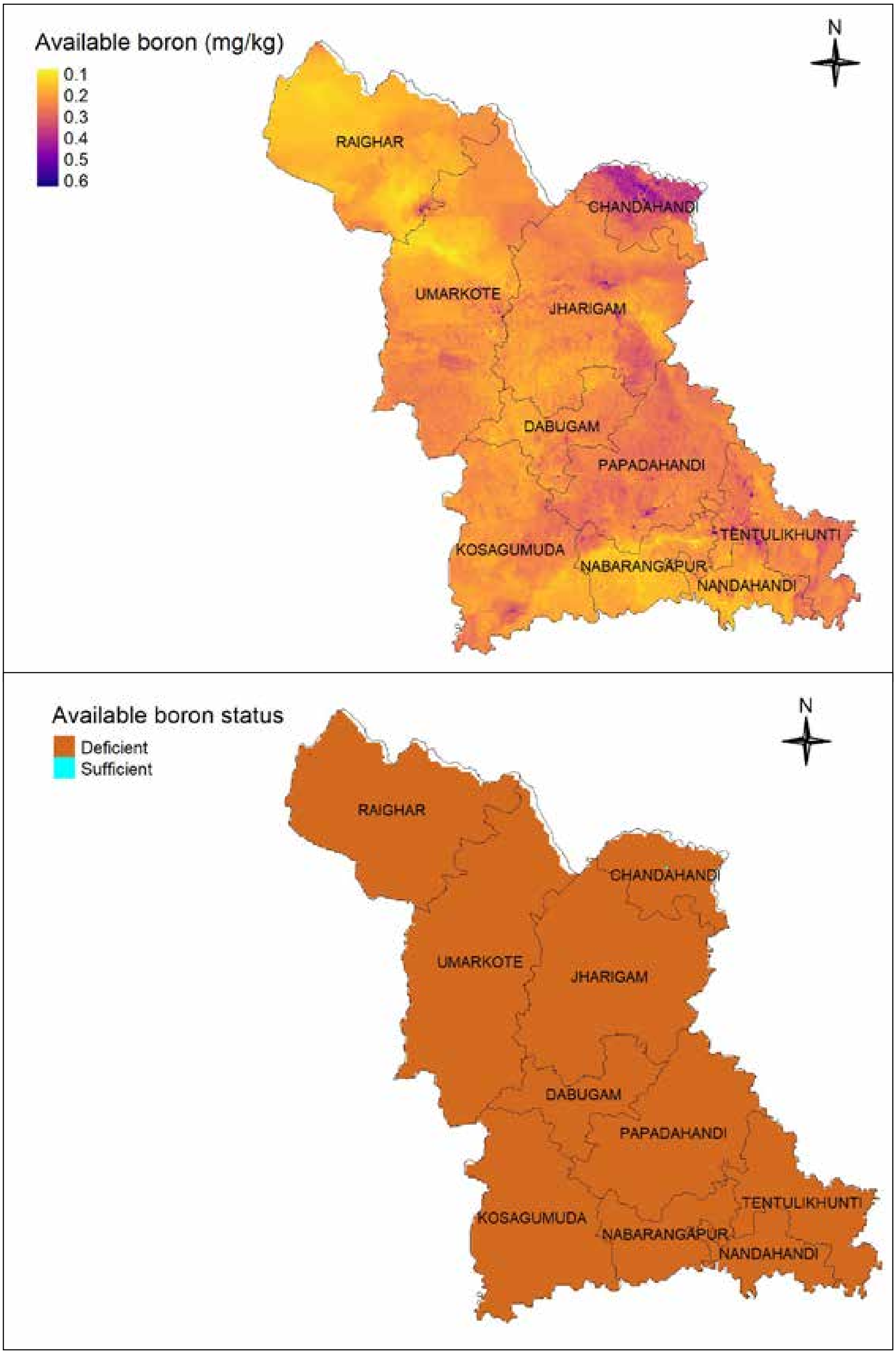


Figure 5.208. Status of available boron in soils of Nabarangpur district.

Available Zinc

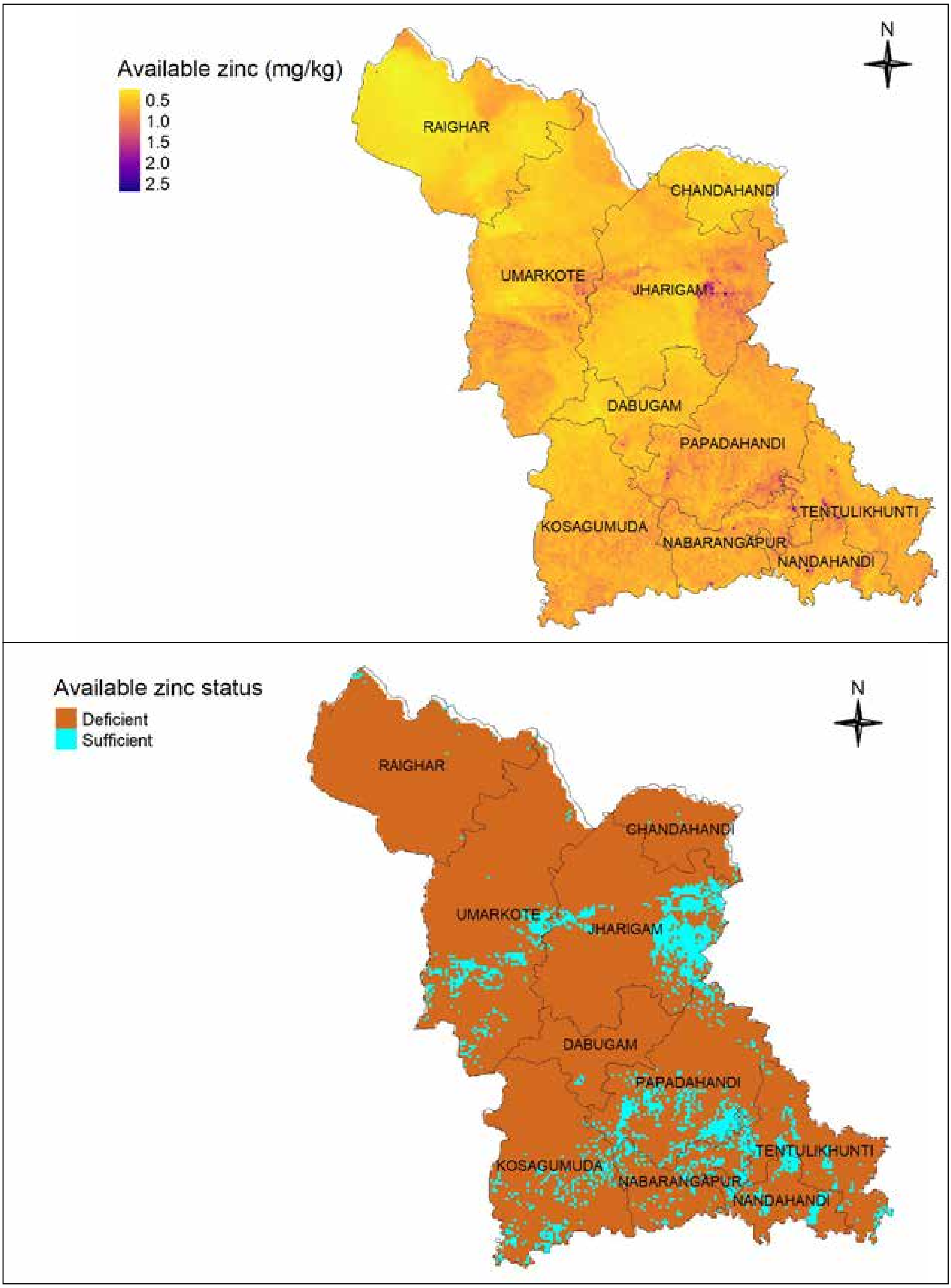


Figure 5.209. Status of available zinc in soils of Nabarangpur district.

Nayagarh | pH

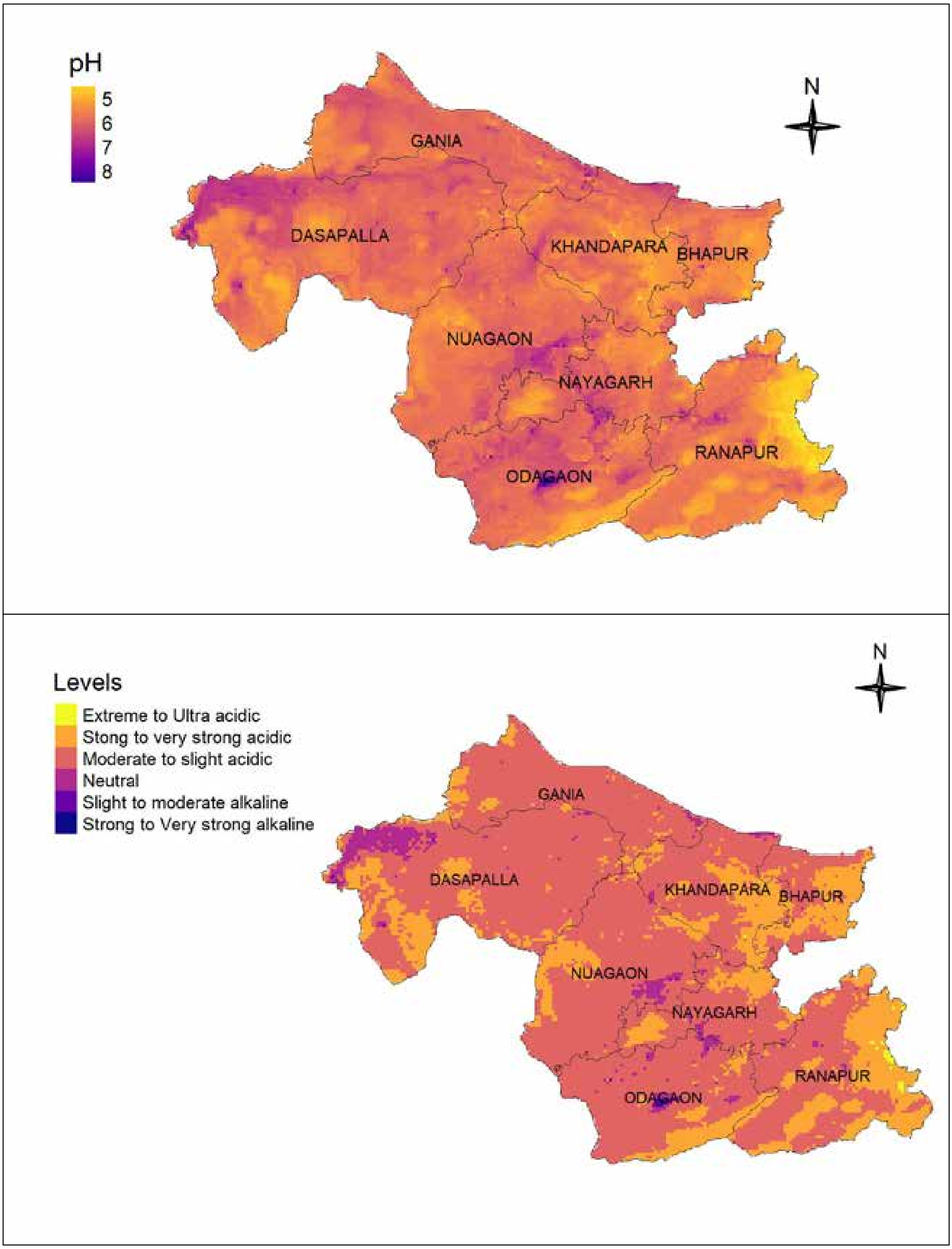


Figure. 5.210. pH status in soils of Nayagarh district.

Electrical conductivity

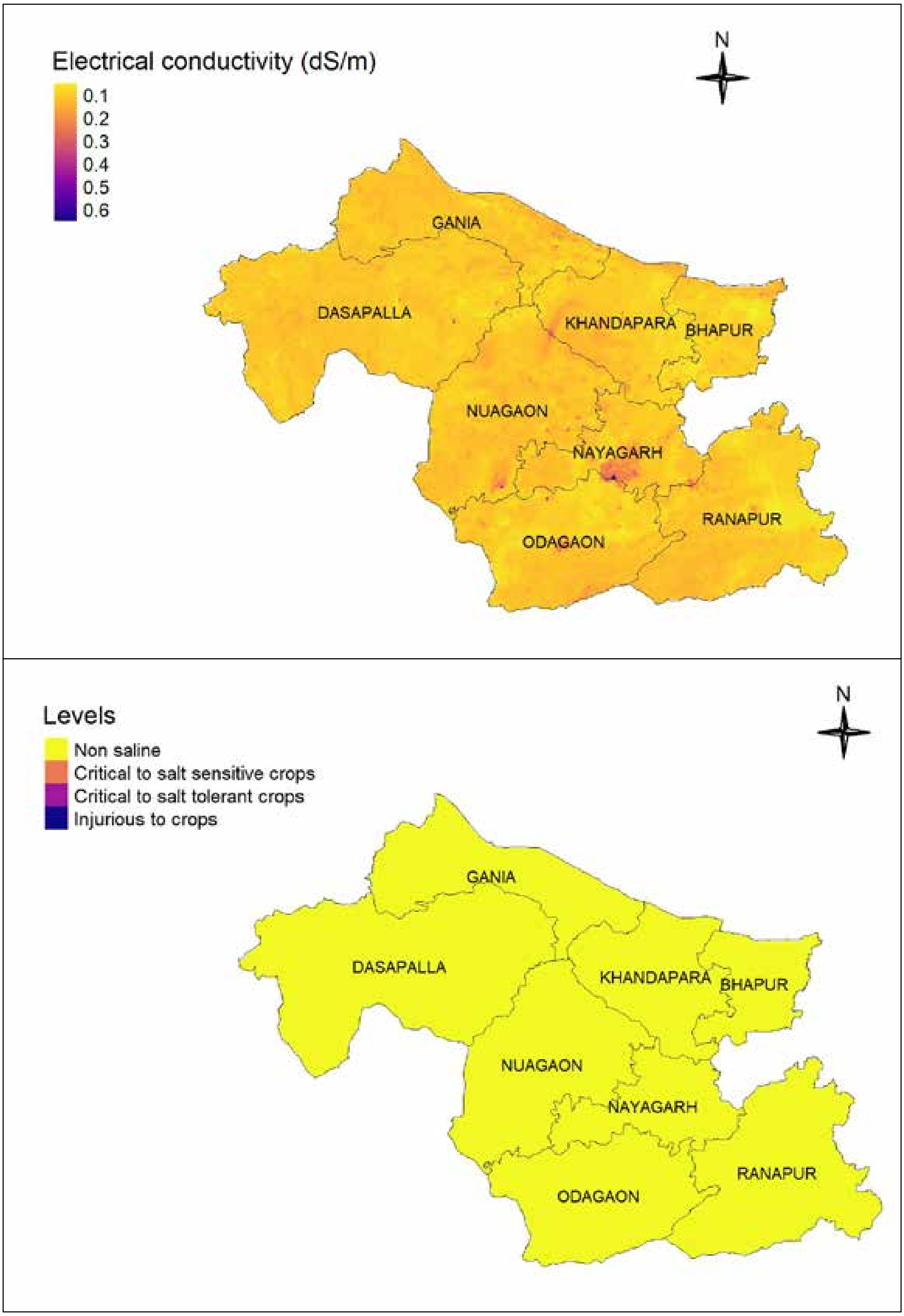


Figure 5.211. Status of electrical conductivity in soils of Nayagarh district.

Organic carbon

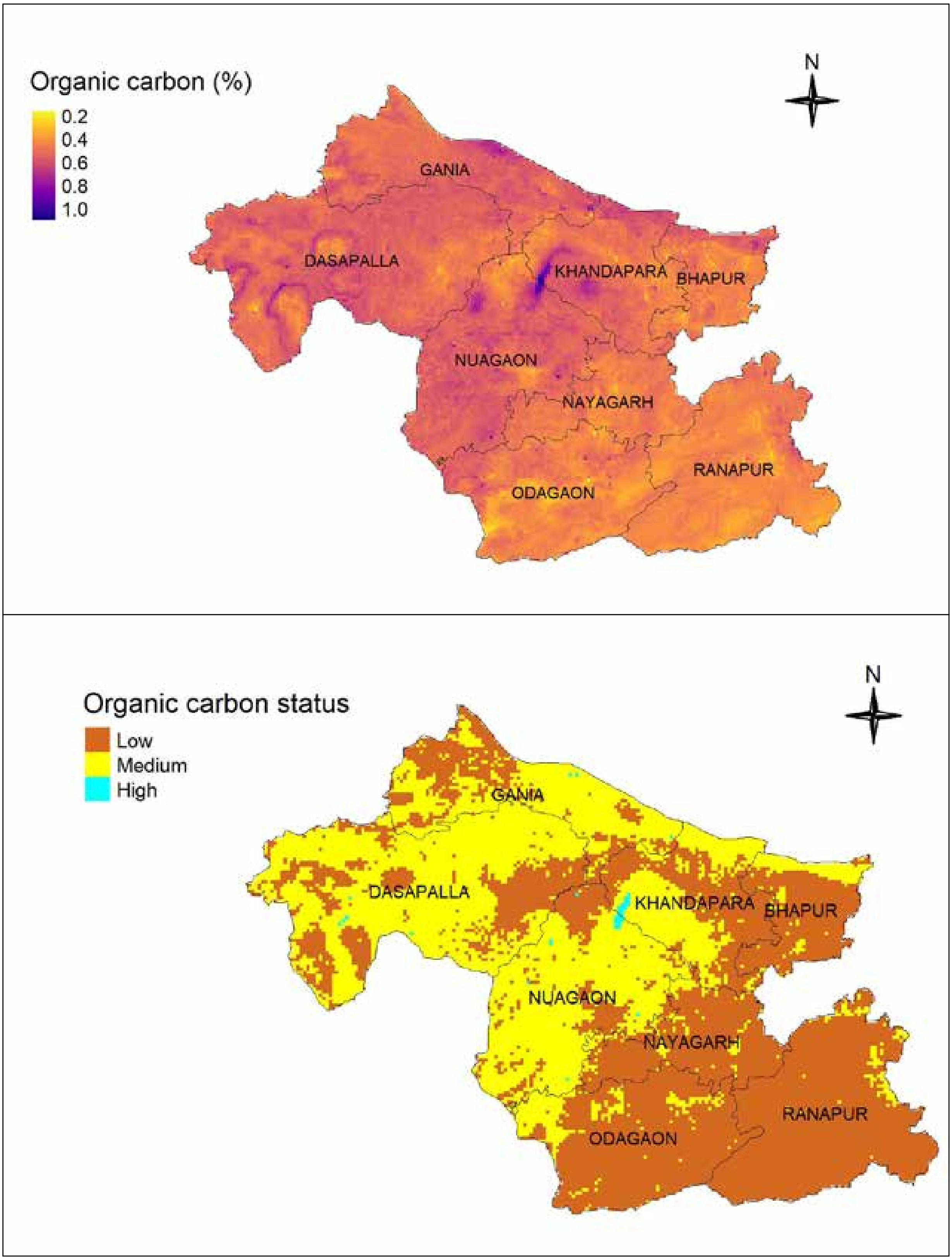


Figure 5.212. Organic carbon status in soils of Nayagarh district.

Available Phosphorous

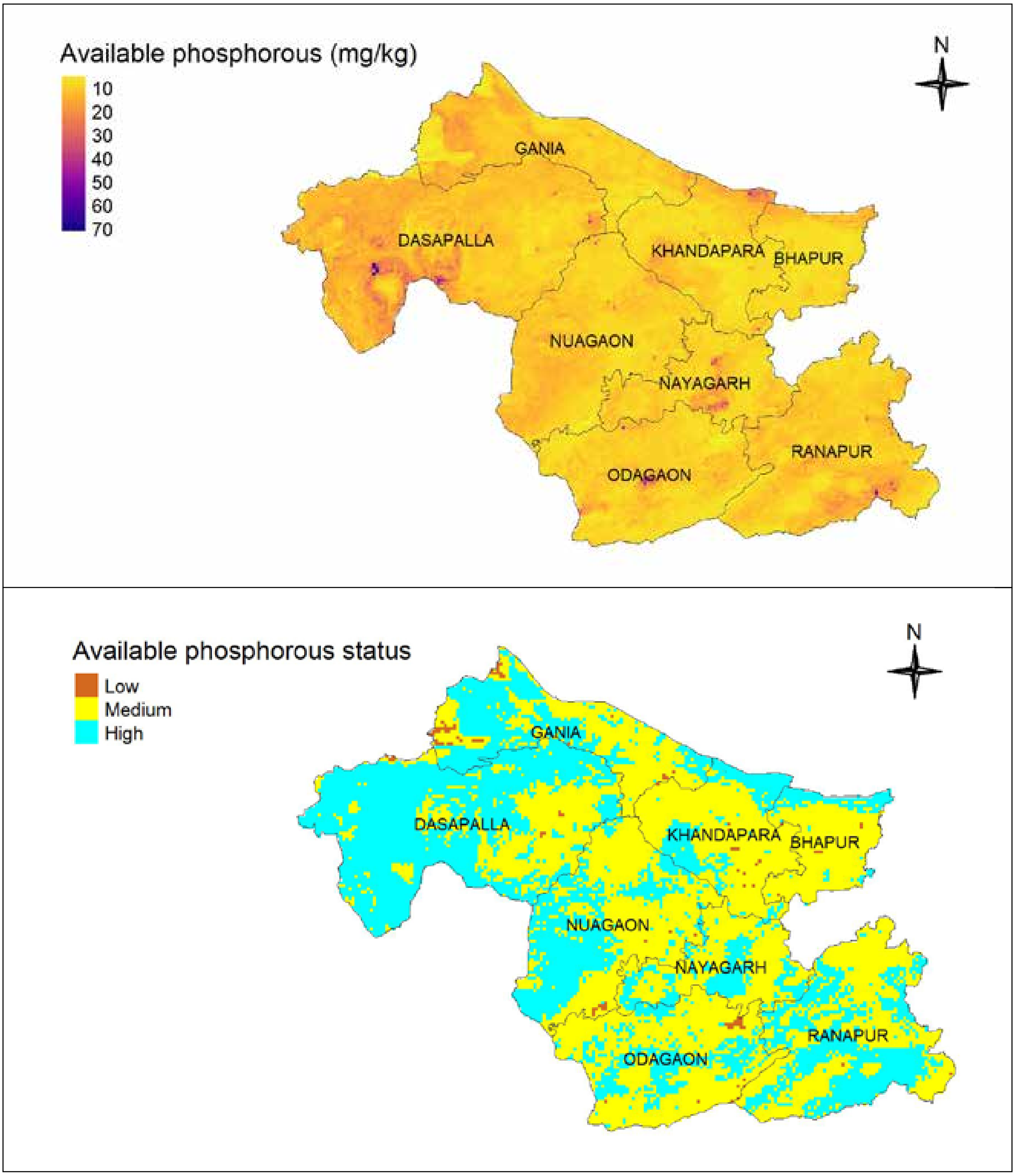


Figure 5.213. Status of available phosphorous in soils of Nayagarh district.

Exchangeable Potassium

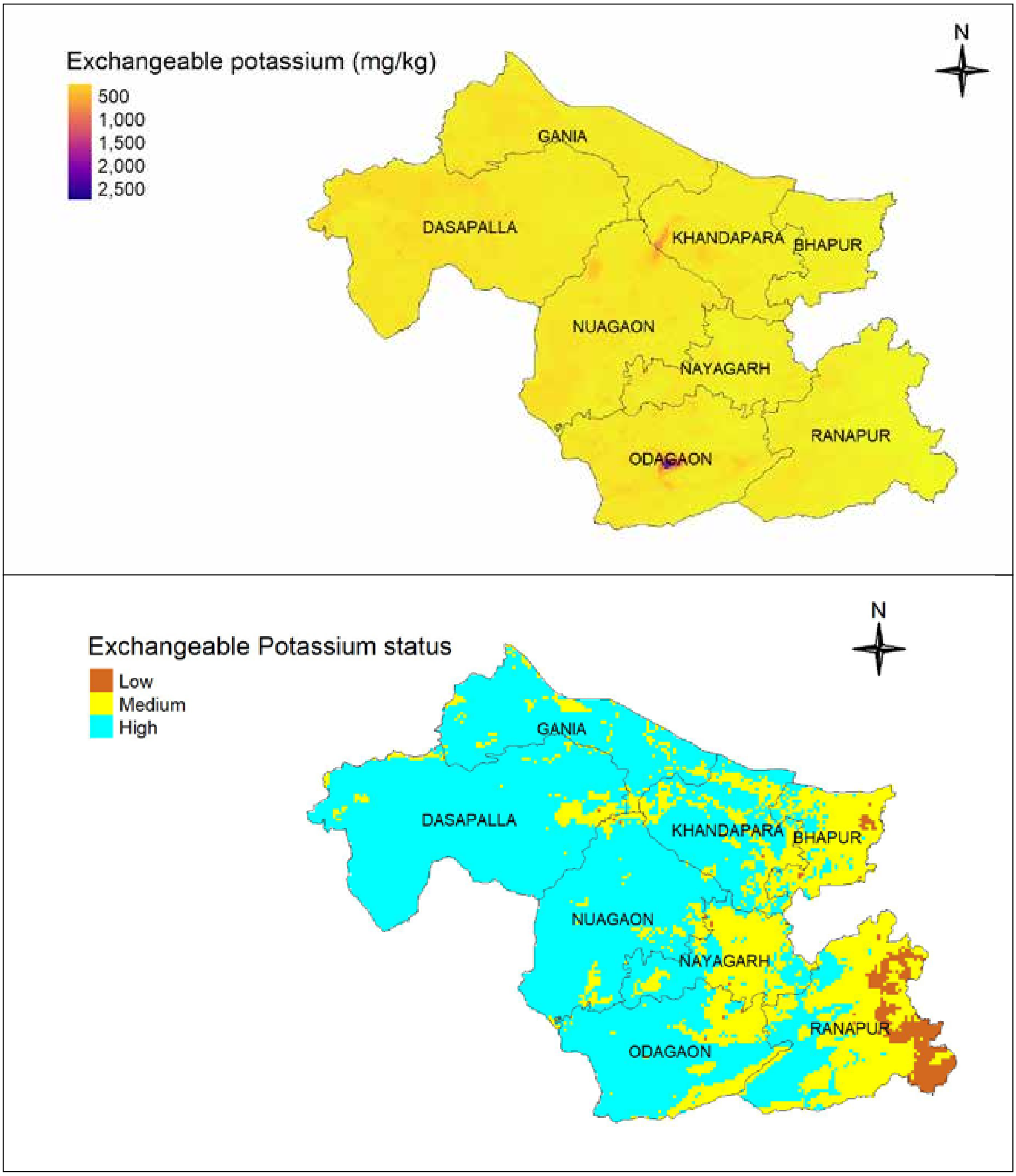


Figure 5.214. Status of exchangeable potassium in soils of Nayagarh district.

Available Sulfur

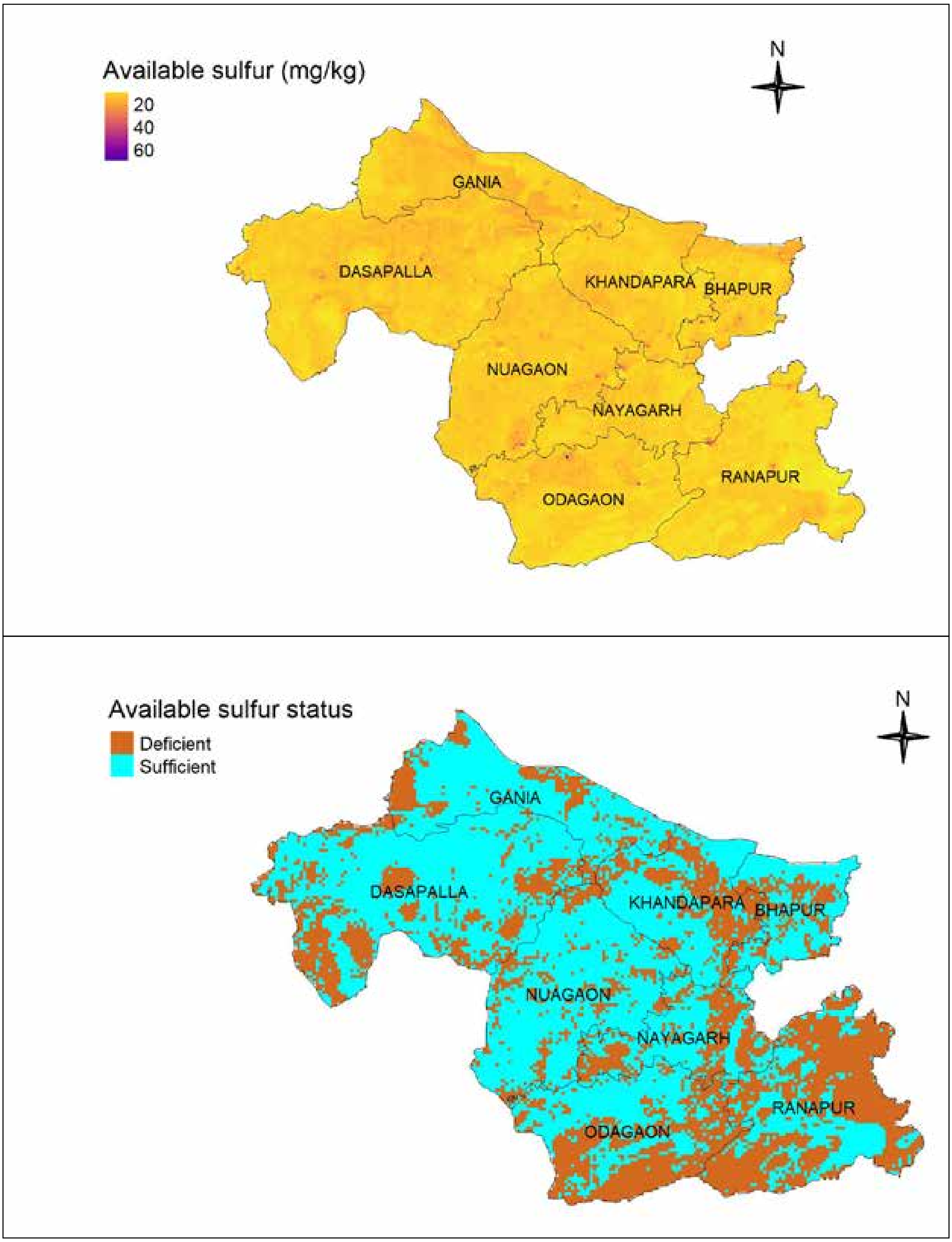


Figure 5.215. Status of available sulfur in soils of Nayagarh district.

Available Boron

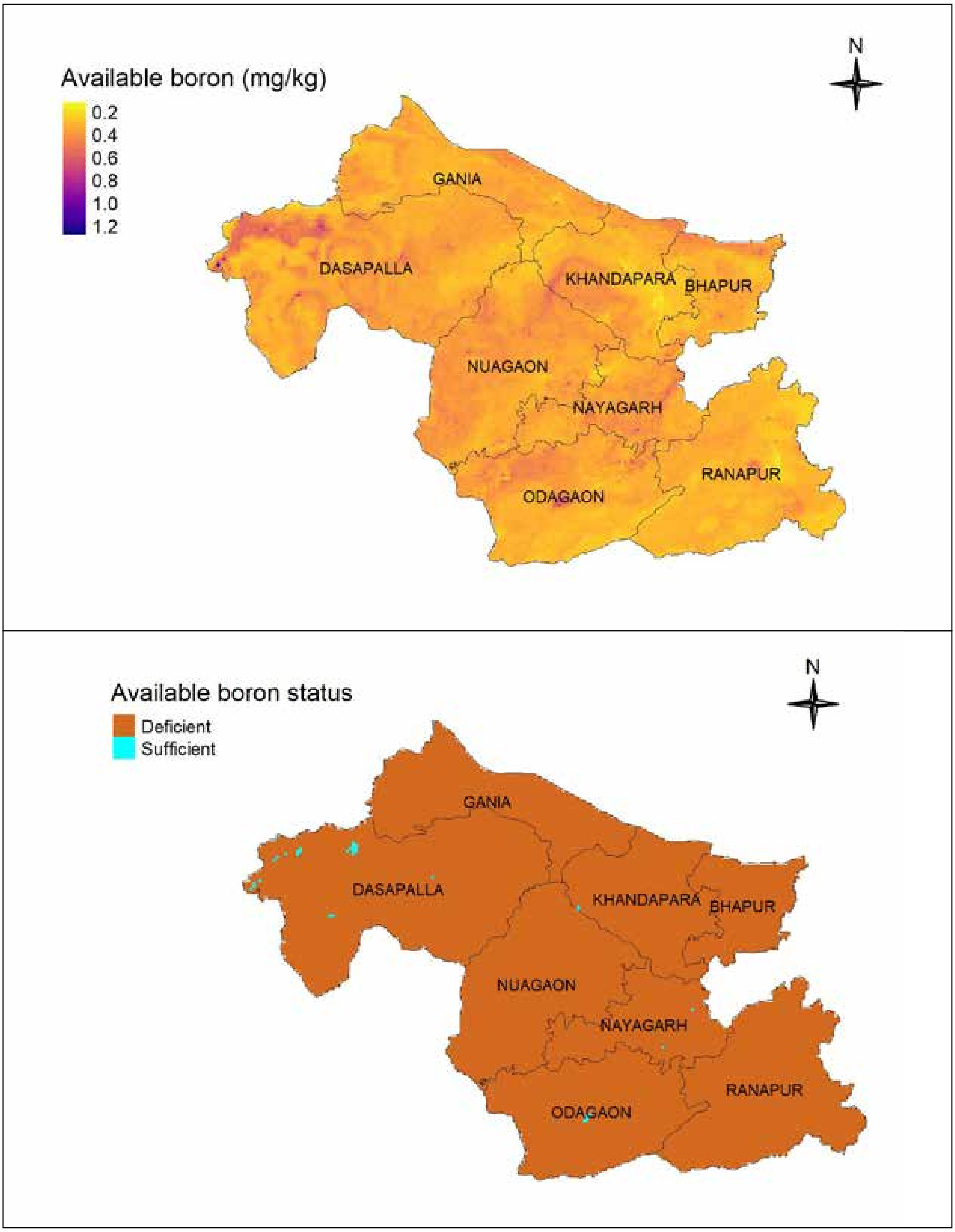


Figure 5.216. Status of available boron in soils of Nayagarh district.

Available Zinc

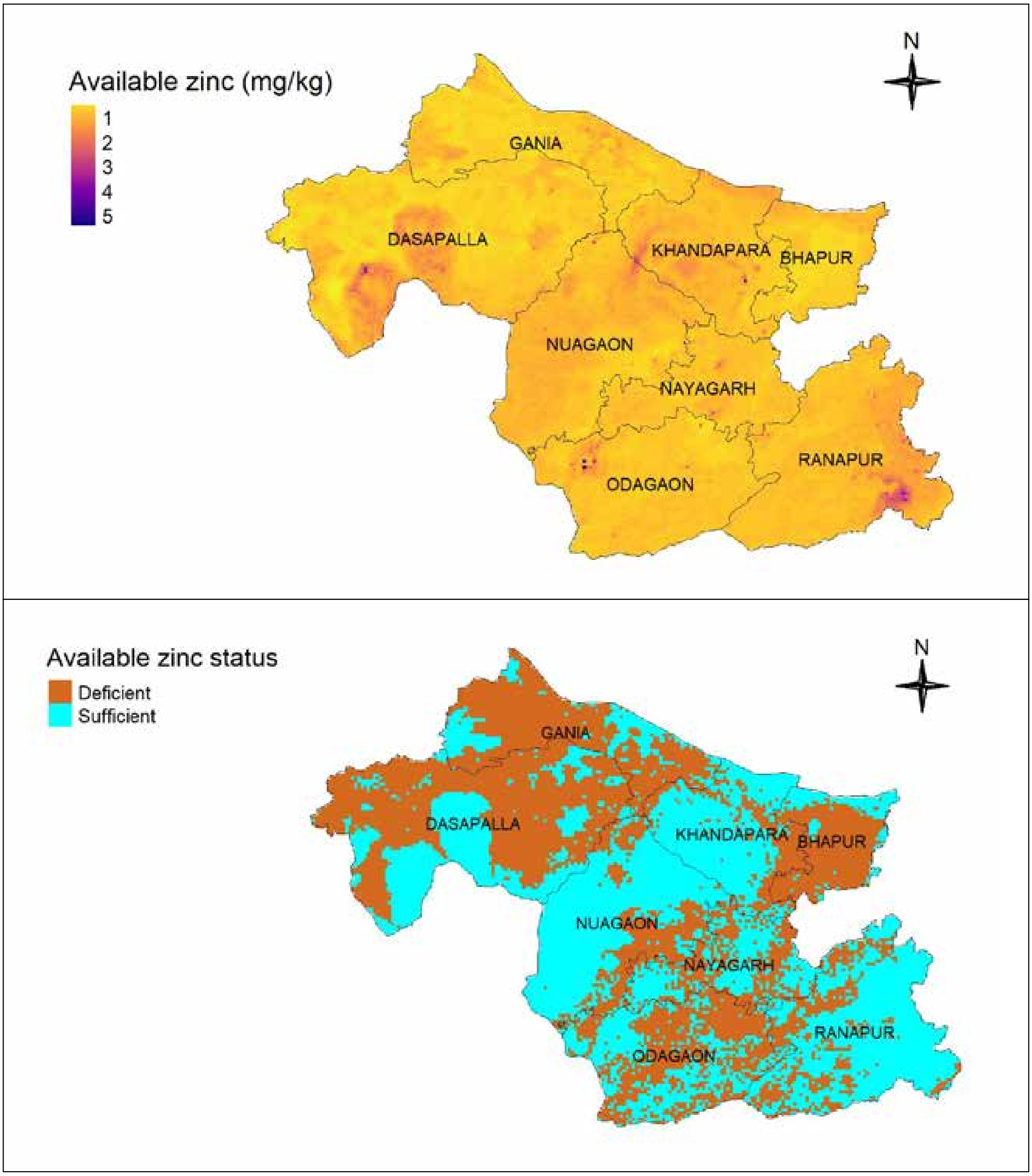


Figure 5.217. Status of available zinc in soils of Nayagarh district.

Nuapada | pH

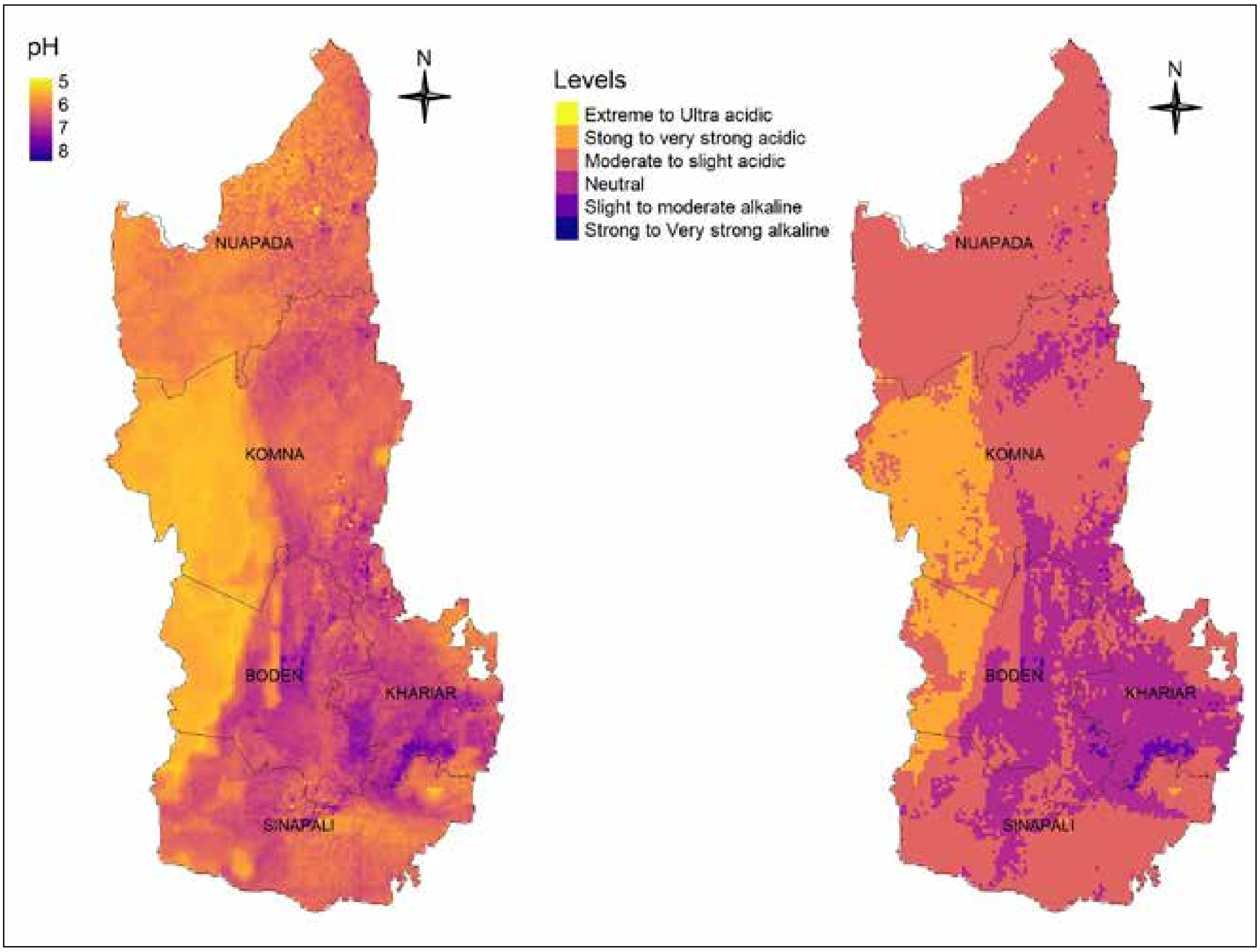


Figure 5.218. pH status in soils of Nuapada district.

Electrical conductivity

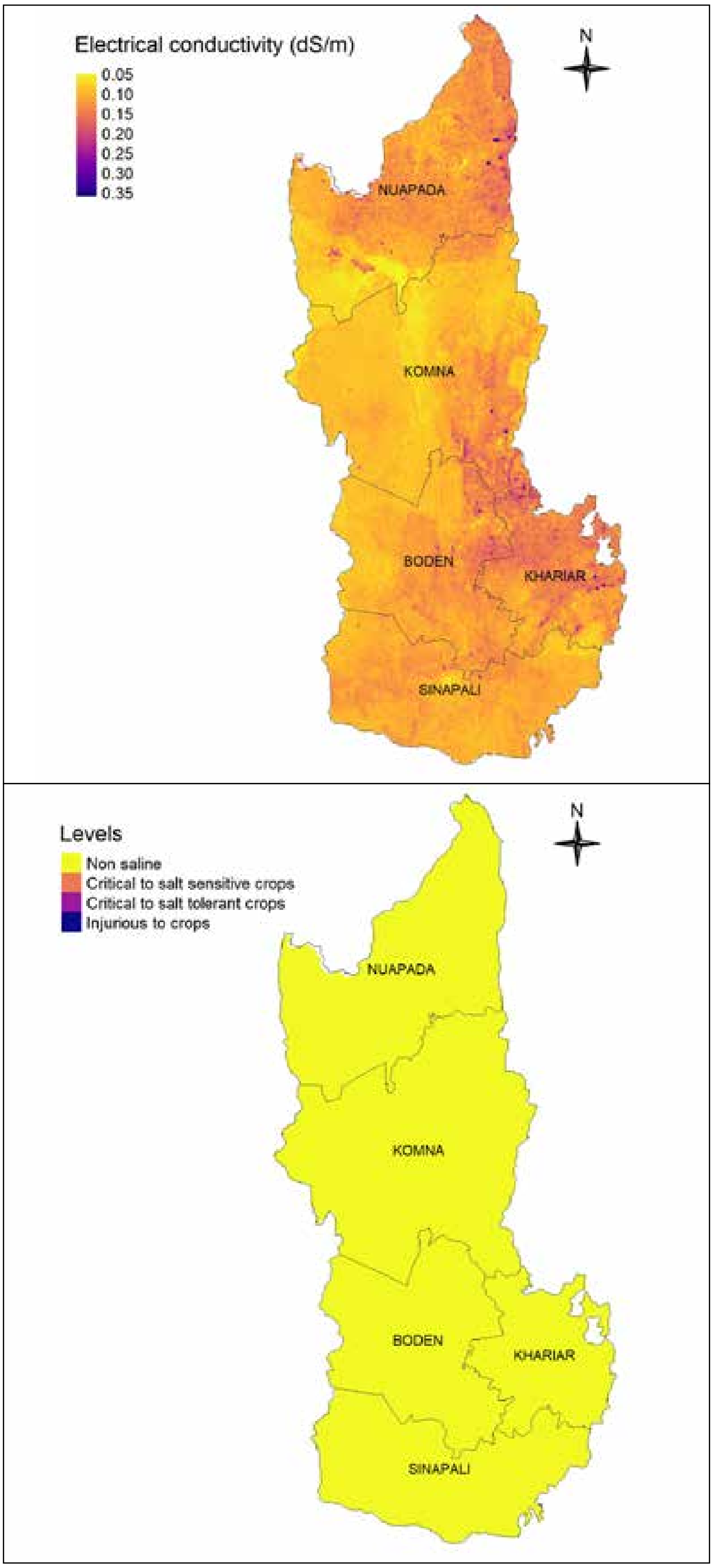


Figure 5.219. Status of electrical conductivity in soils of Nuapada district.

Organic carbon

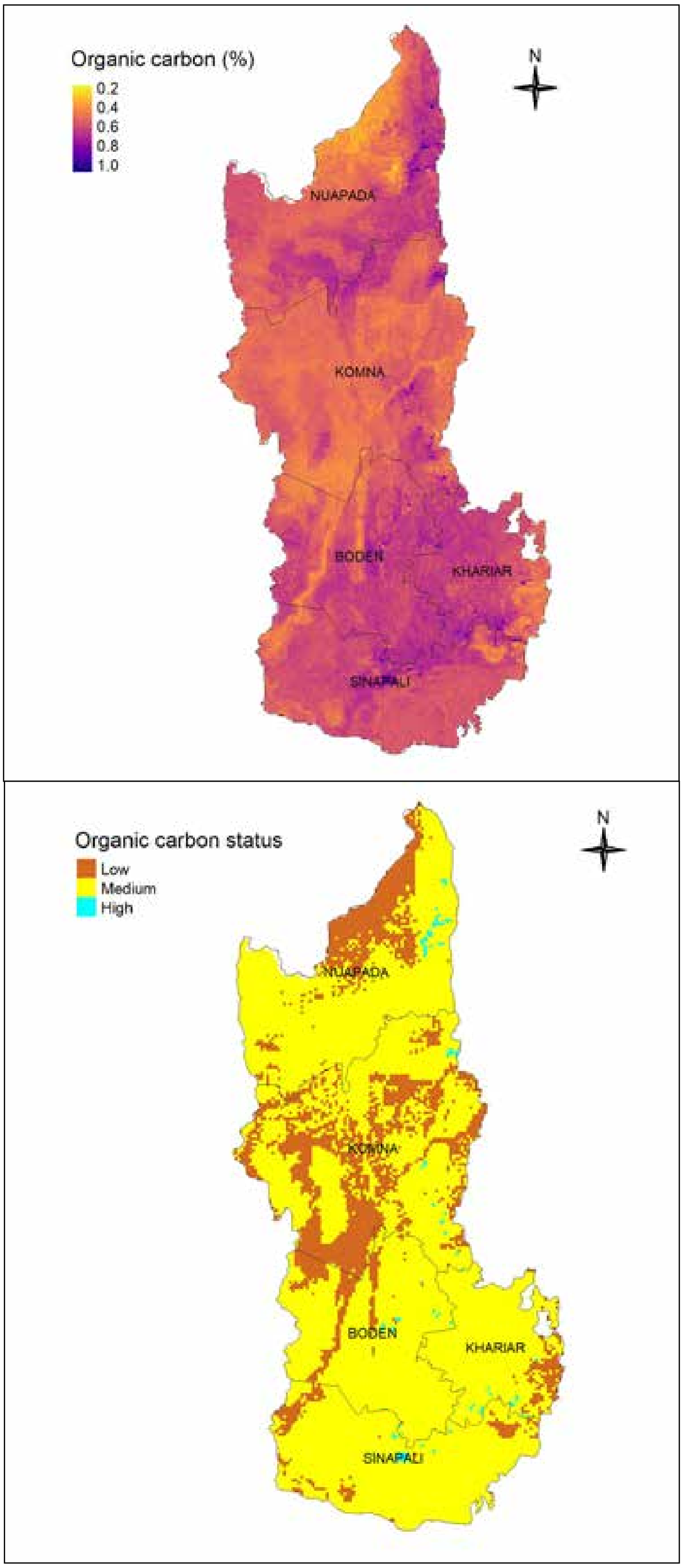


Figure 5.220. Organic carbon status in soils of Nuapada district.

Available Phosphorous

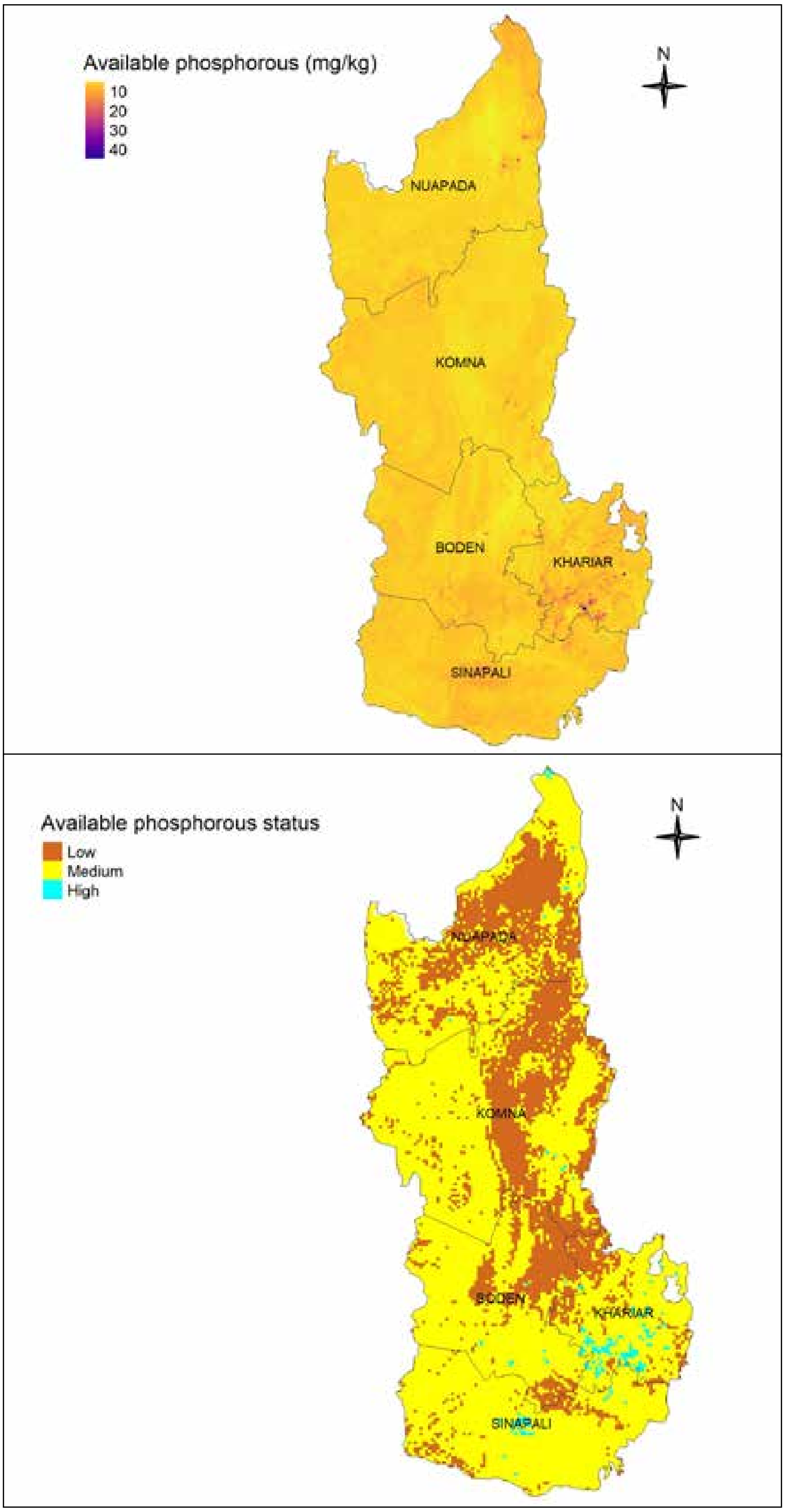


Figure 5.221. Status of available phosphorous in soils of Nuapada district.

Exchangeable Potassium

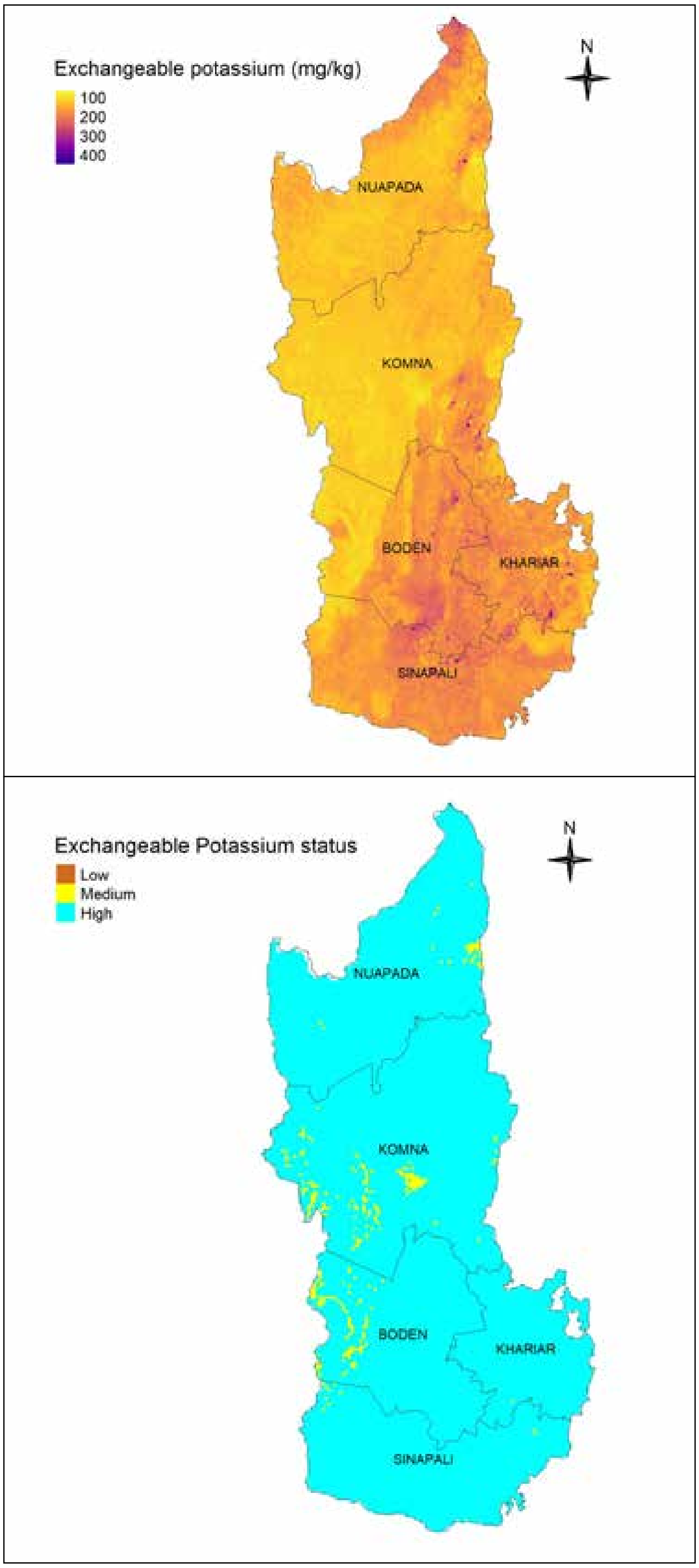


Figure 5.222. Status of exchangeable potassium in soils of Nuapada district.

Available Sulfur

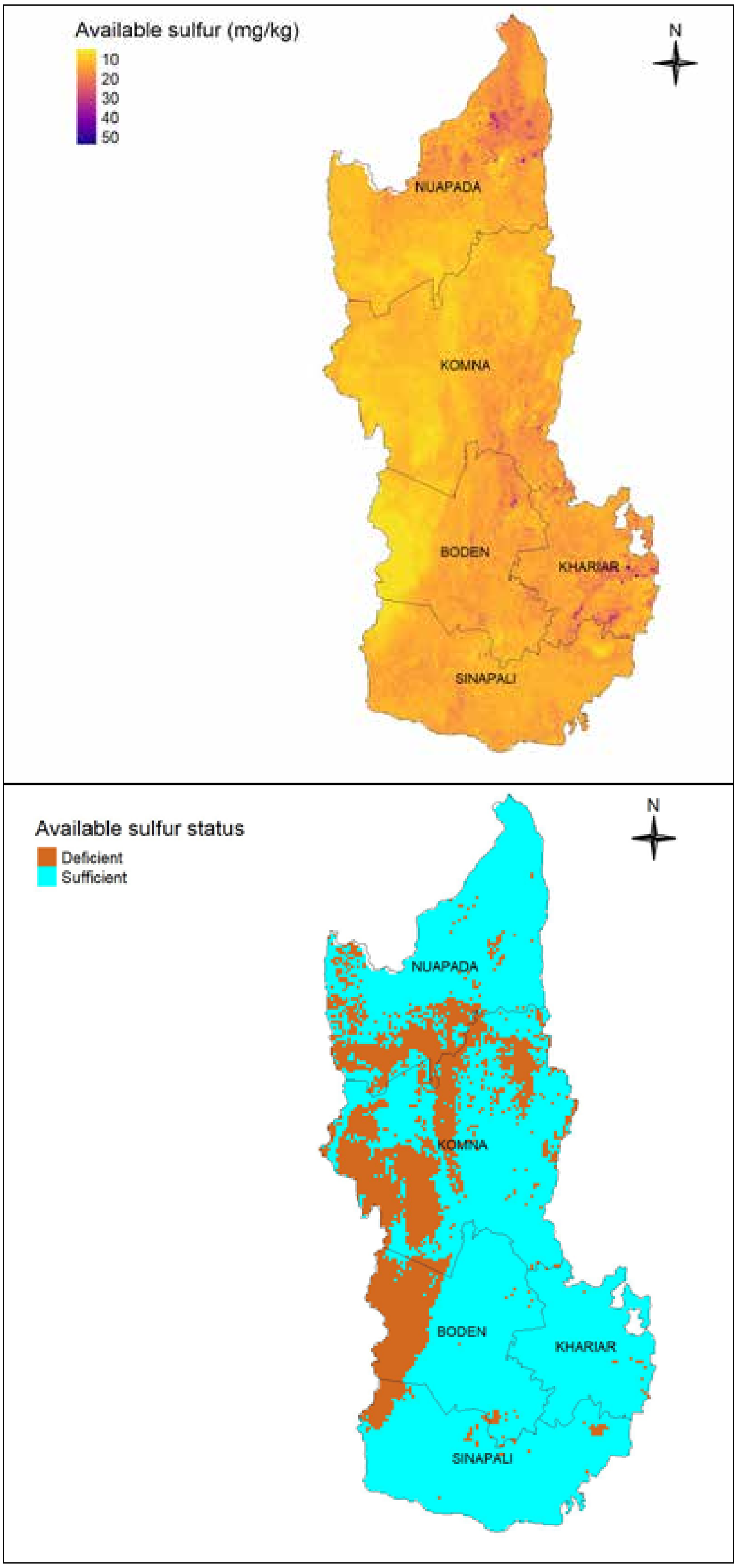


Figure 5.223. Status of available sulfur in soils of Nuapada district.

Available Boron

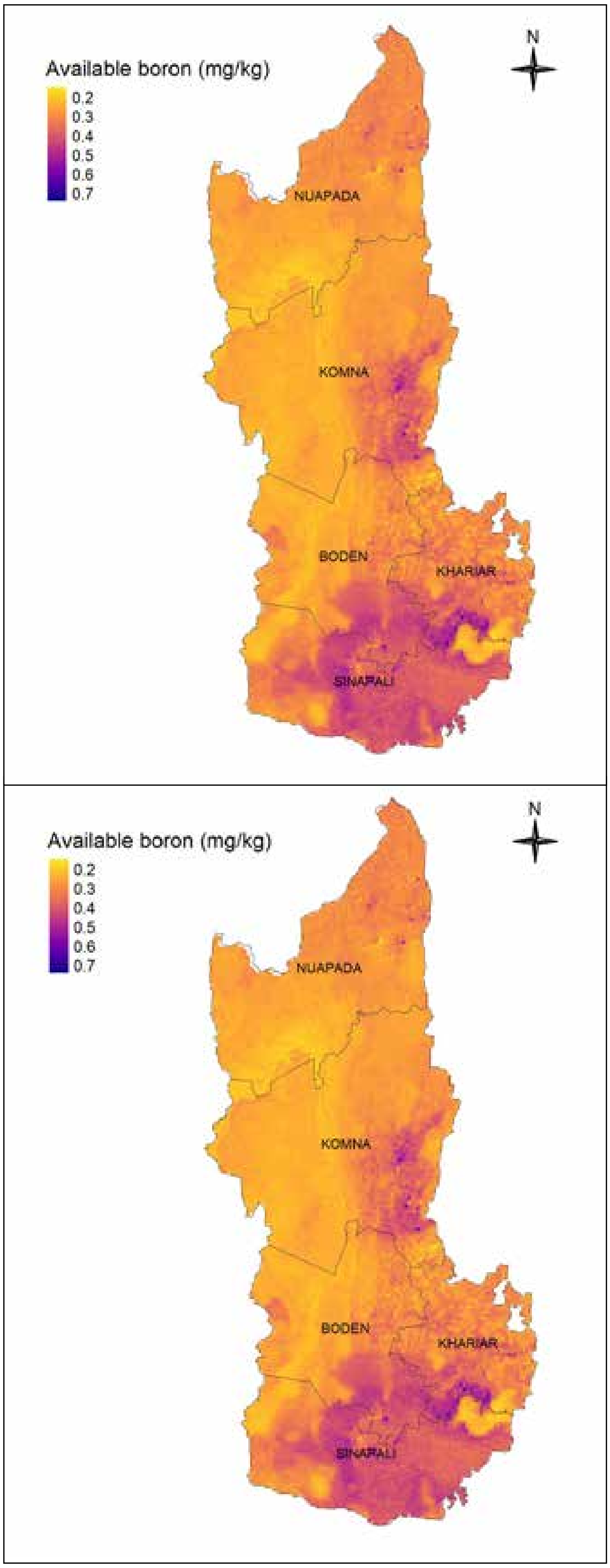


Figure 5.224. Status of available boron in soils of Nuapada district.

Available Zinc

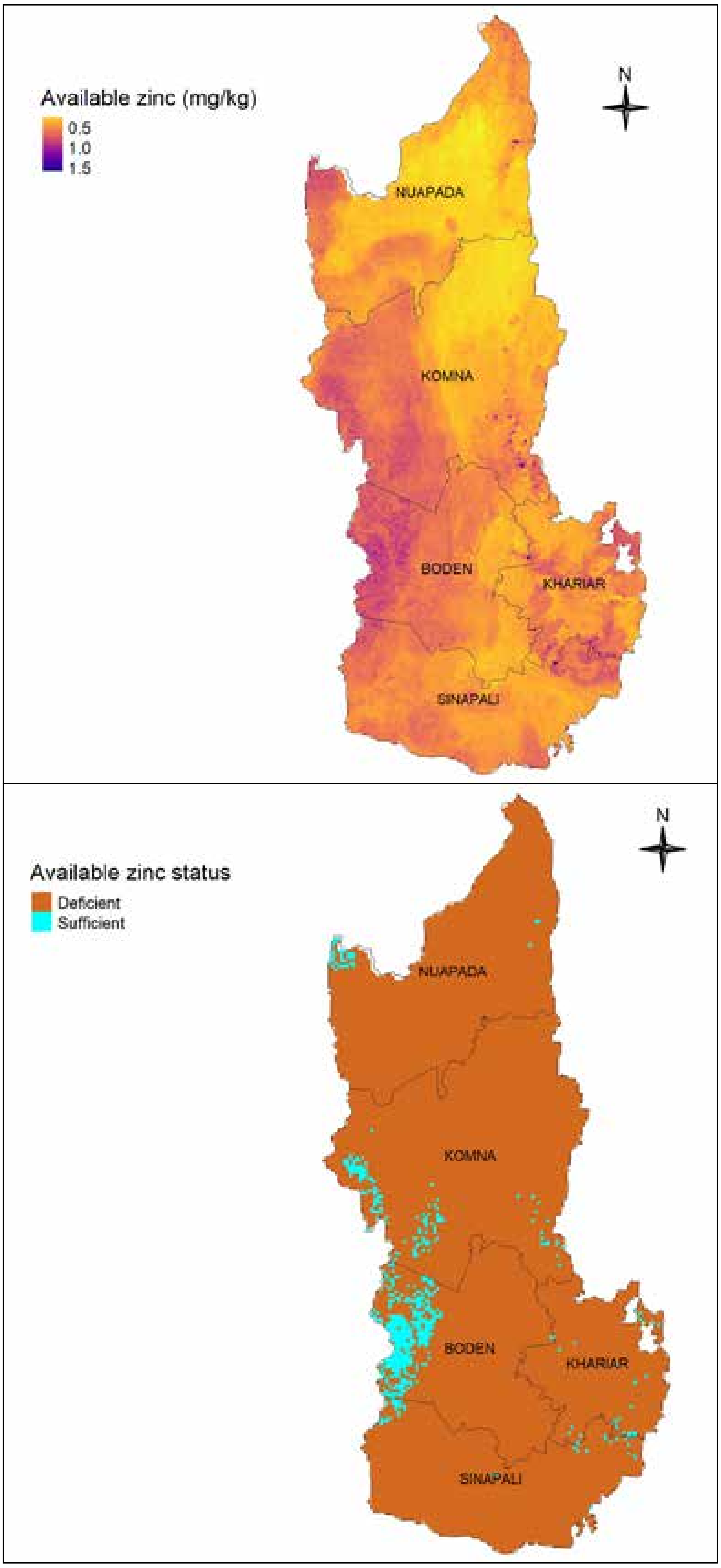


Figure 5.225. Status of available zinc in soils of Nuapada district.

Puri | pH

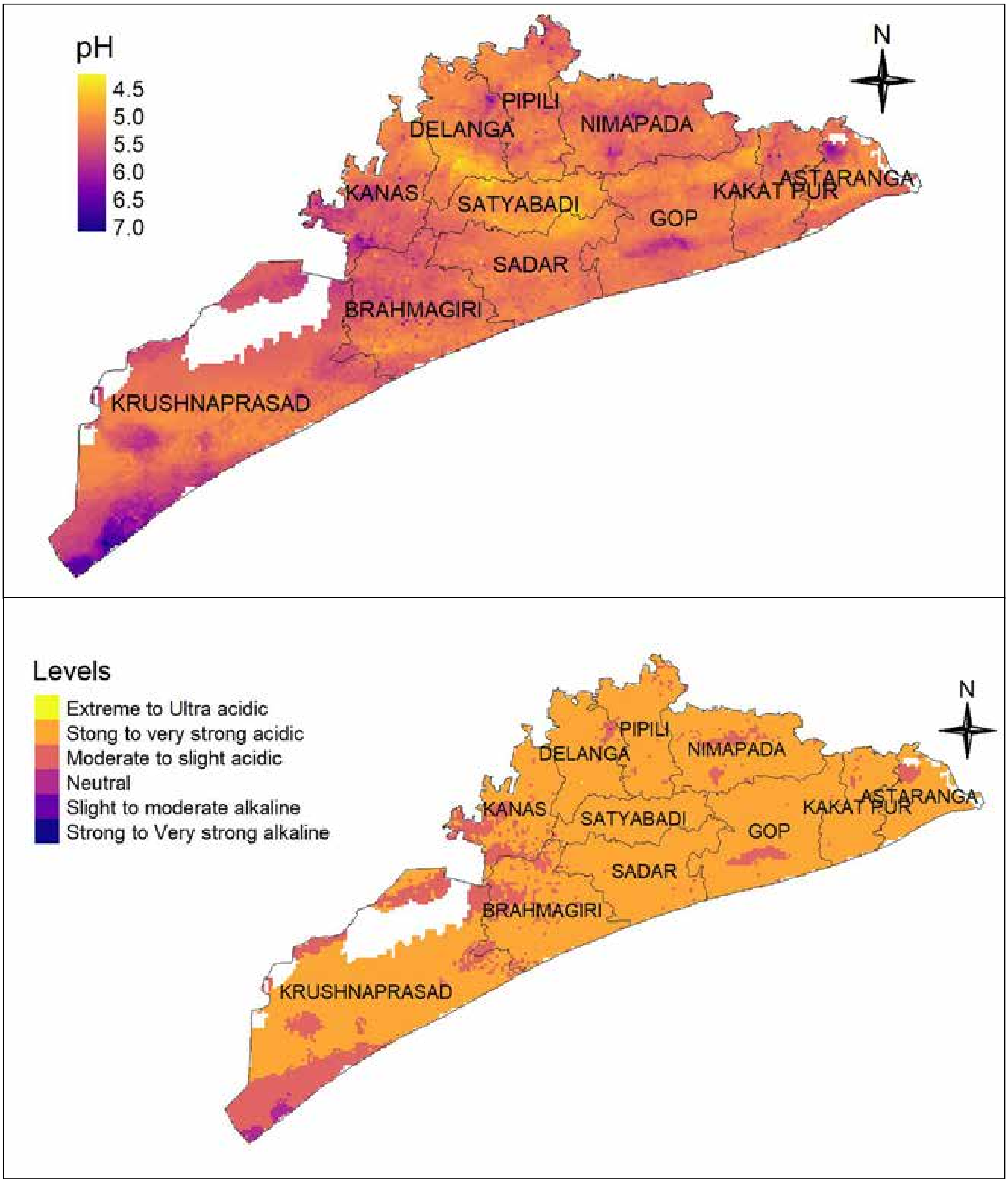


Figure 5.226. pH status in soils of Puri district.

Electrical conductivity

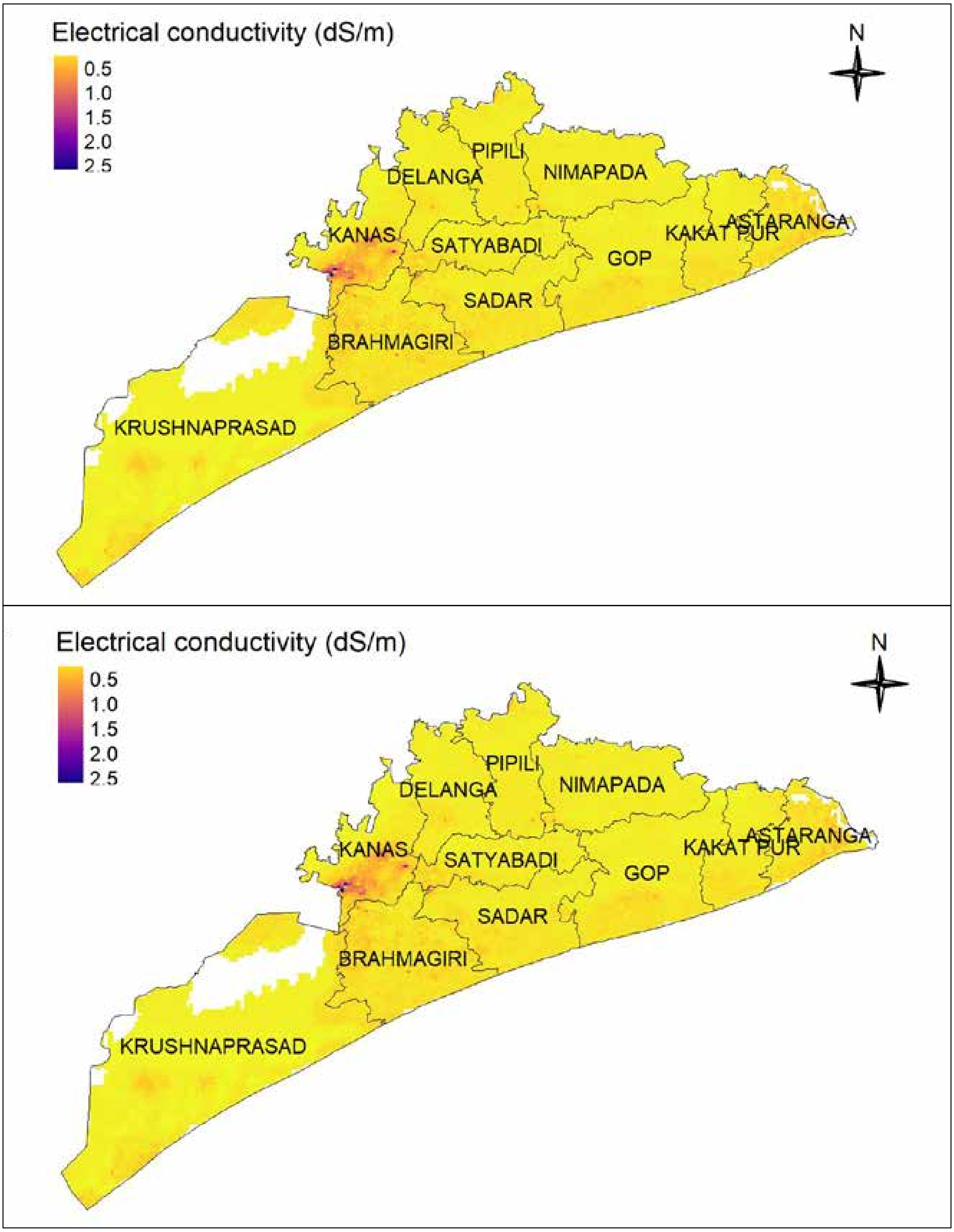


Figure 5.227. Status of electrical conductivity in soils of Puri district.

Organic carbon

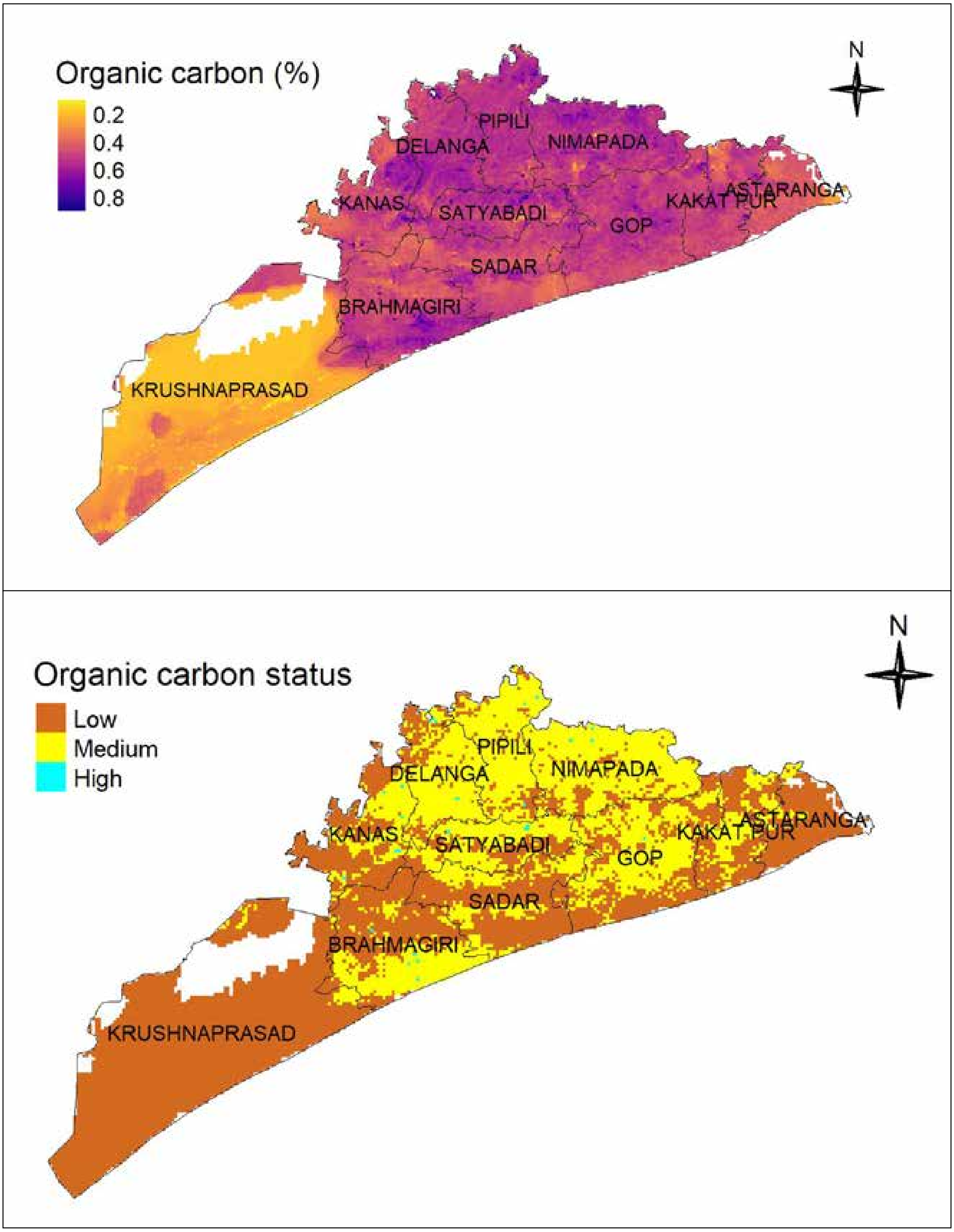


Figure 5.228. Organic carbon status in soils of Puri district.

Available Phosphorous

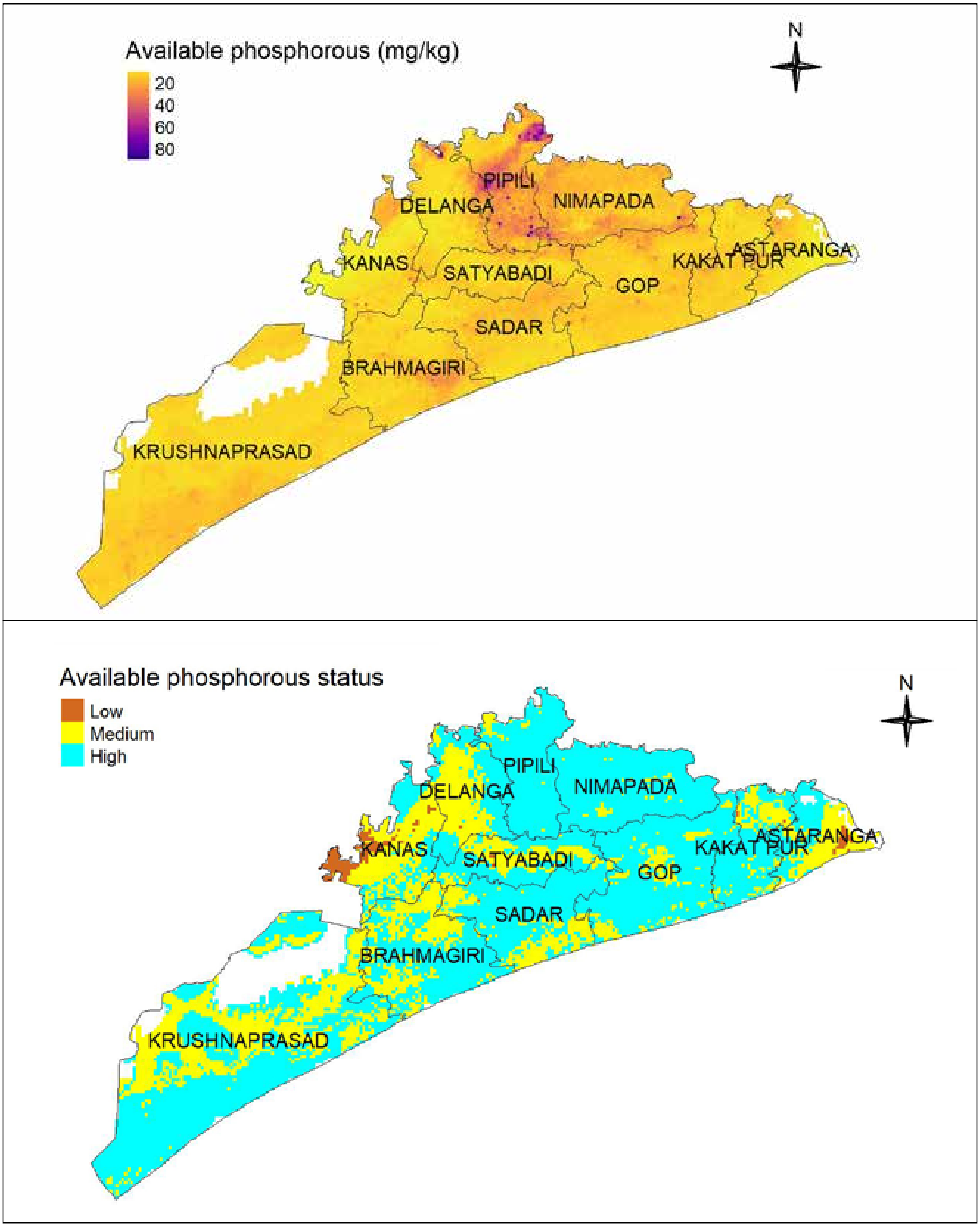


Figure 5.229. Status of available phosphorous in soils of Puri district.

Exchangeable Potassium

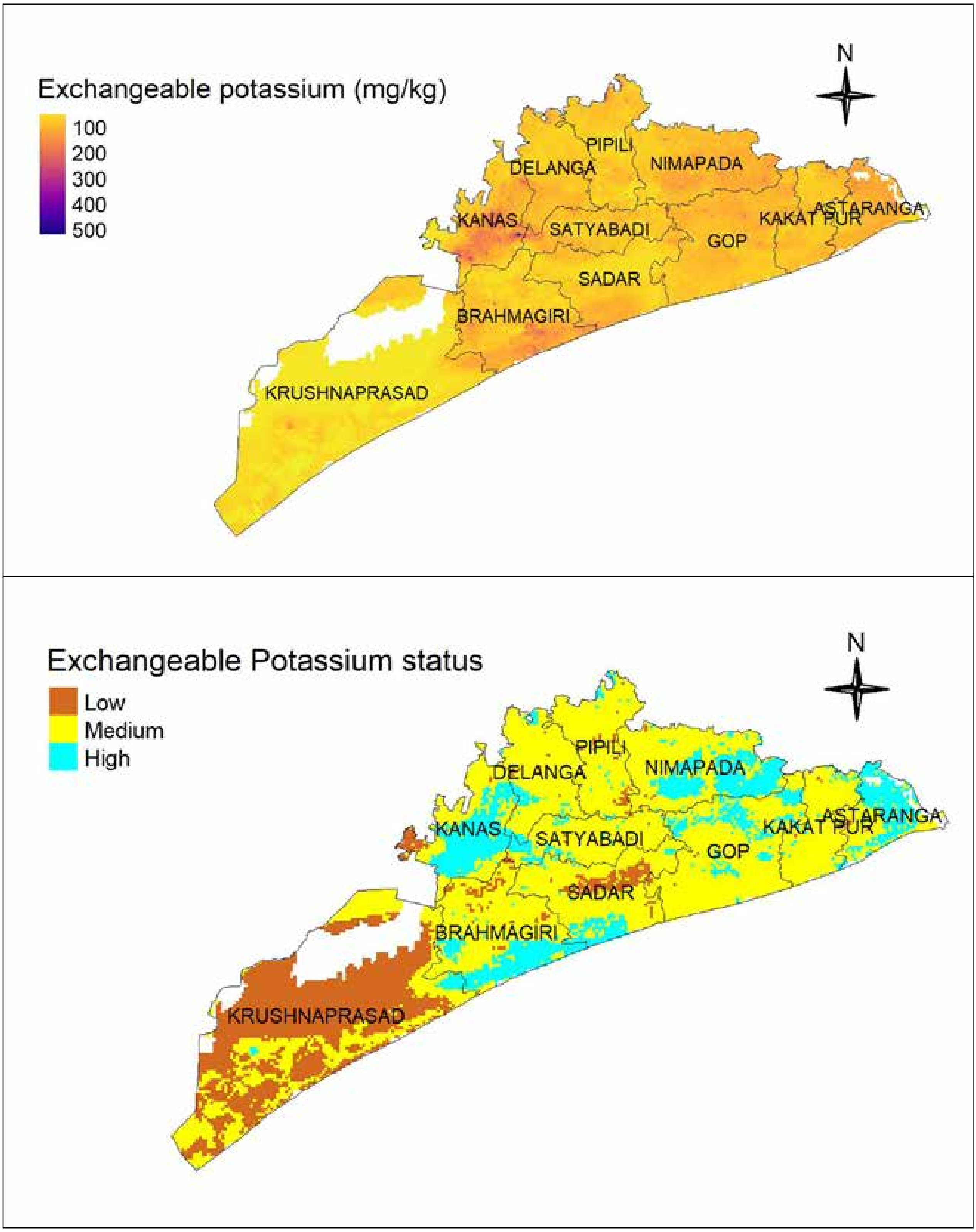


Figure 5.230. Status of exchangeable potassium in soils of Puri district.

Available Sulfur

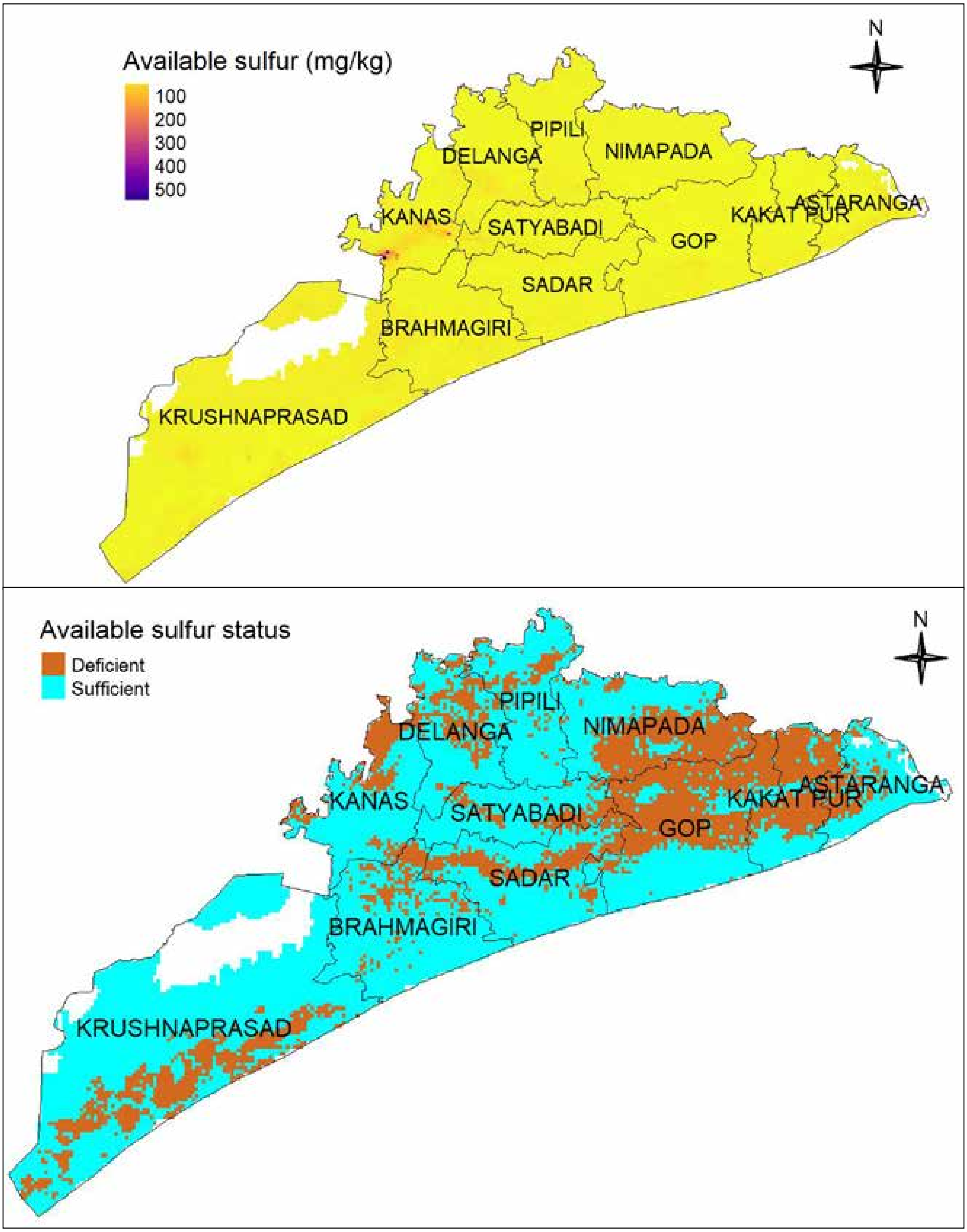


Figure 5.231. Status of available sulfur in soils of Puri district.

Available Boron

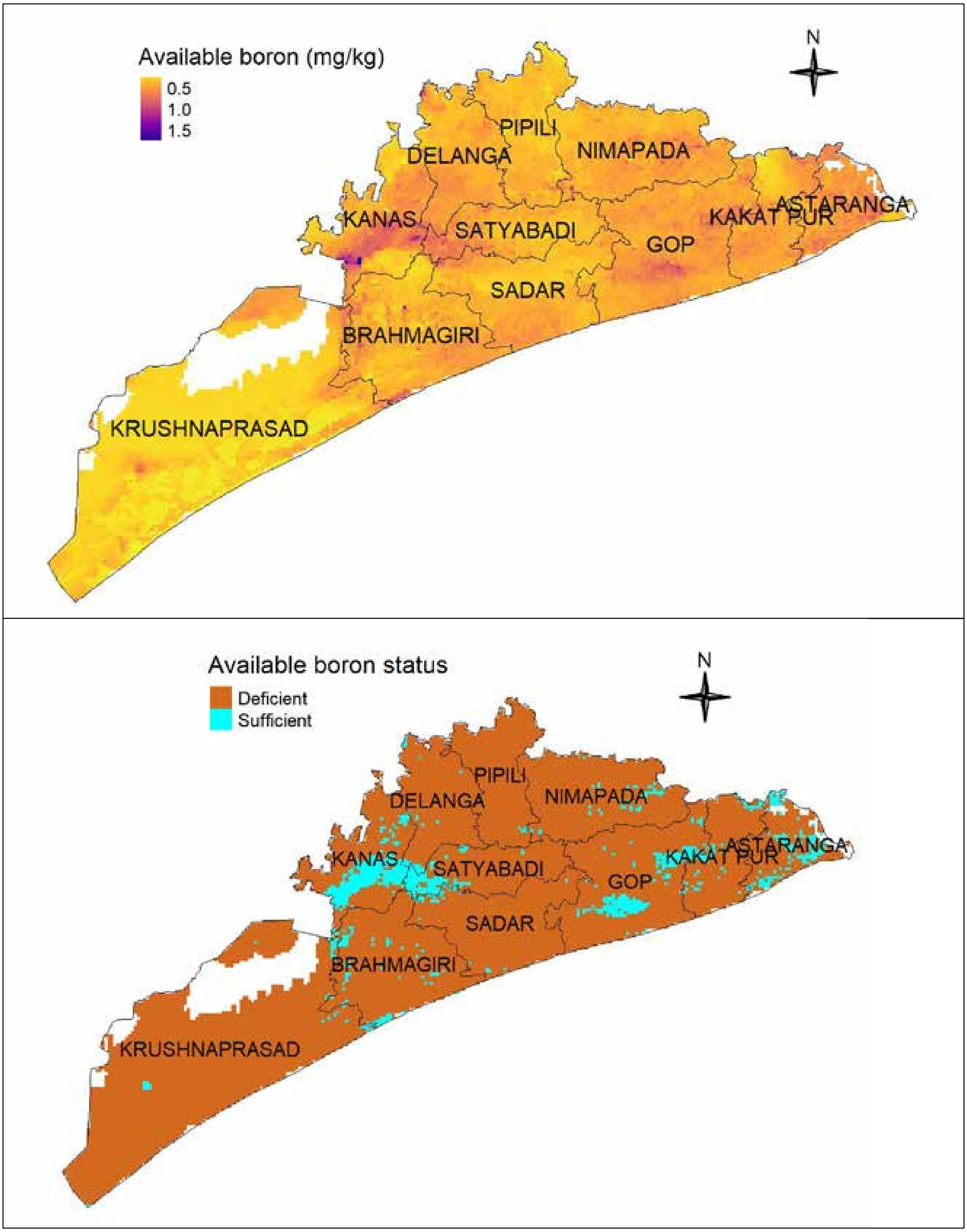


Figure 5.232. Status of available boron in soils of Puri district.

Available Zinc

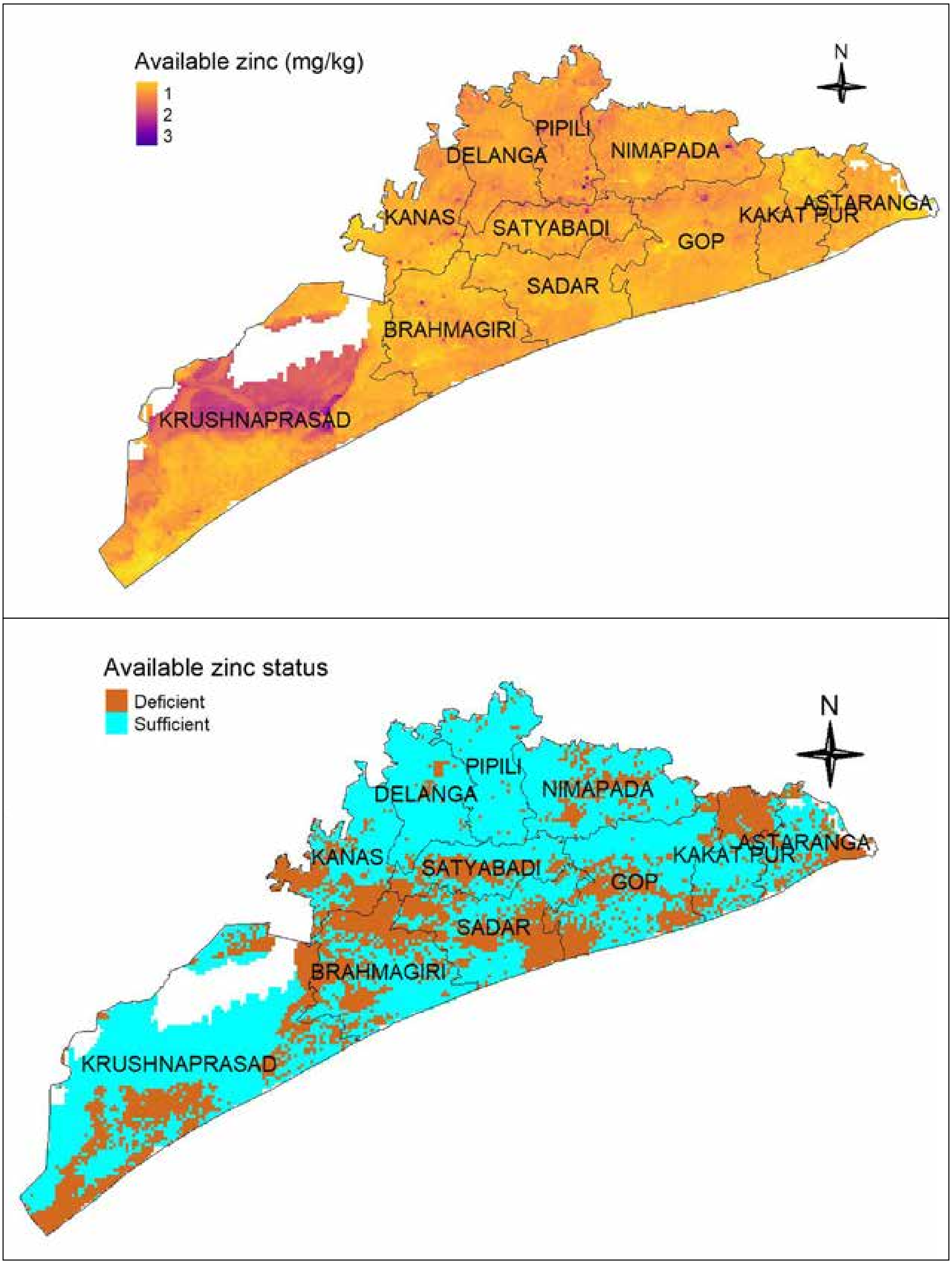


Figure 5.233. Status of available zinc in soils of Puri district.

Rayagada | pH

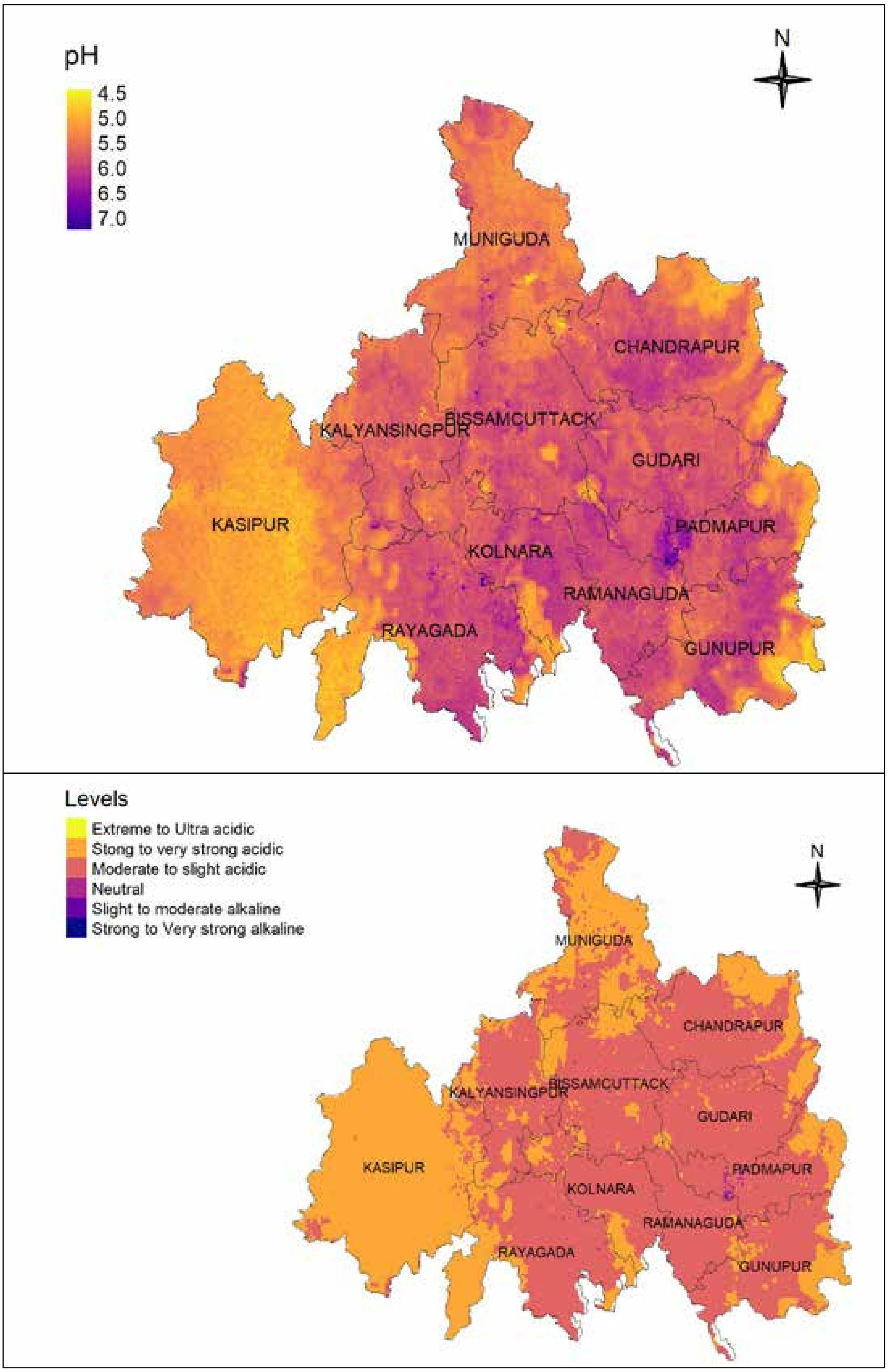


Figure 5.234. pH status in soils of Rayagada district.

Electrical conductivity

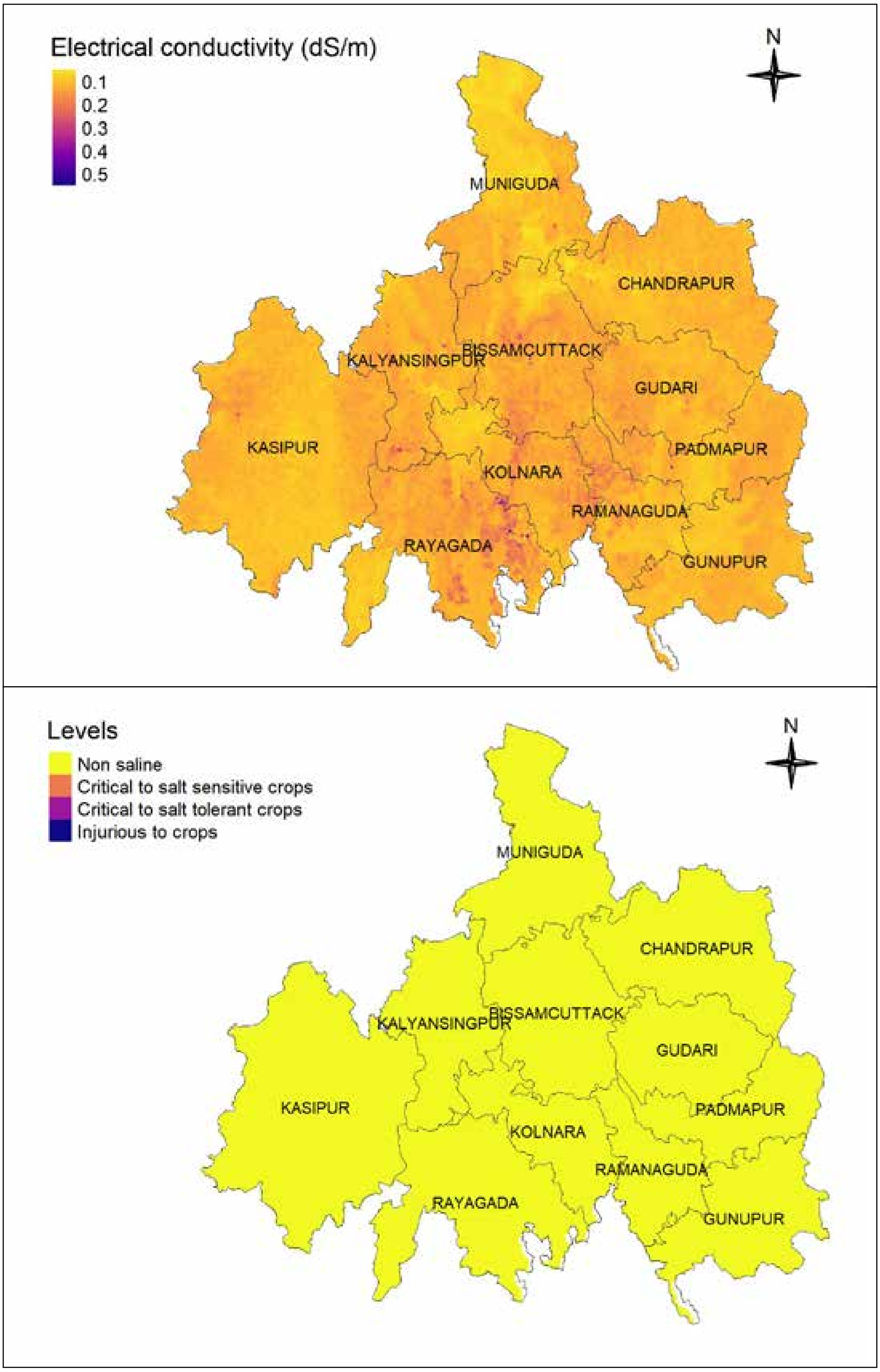


Figure 5.235. Status of electrical conductivity in soils of Rayagada district.

Organic carbon

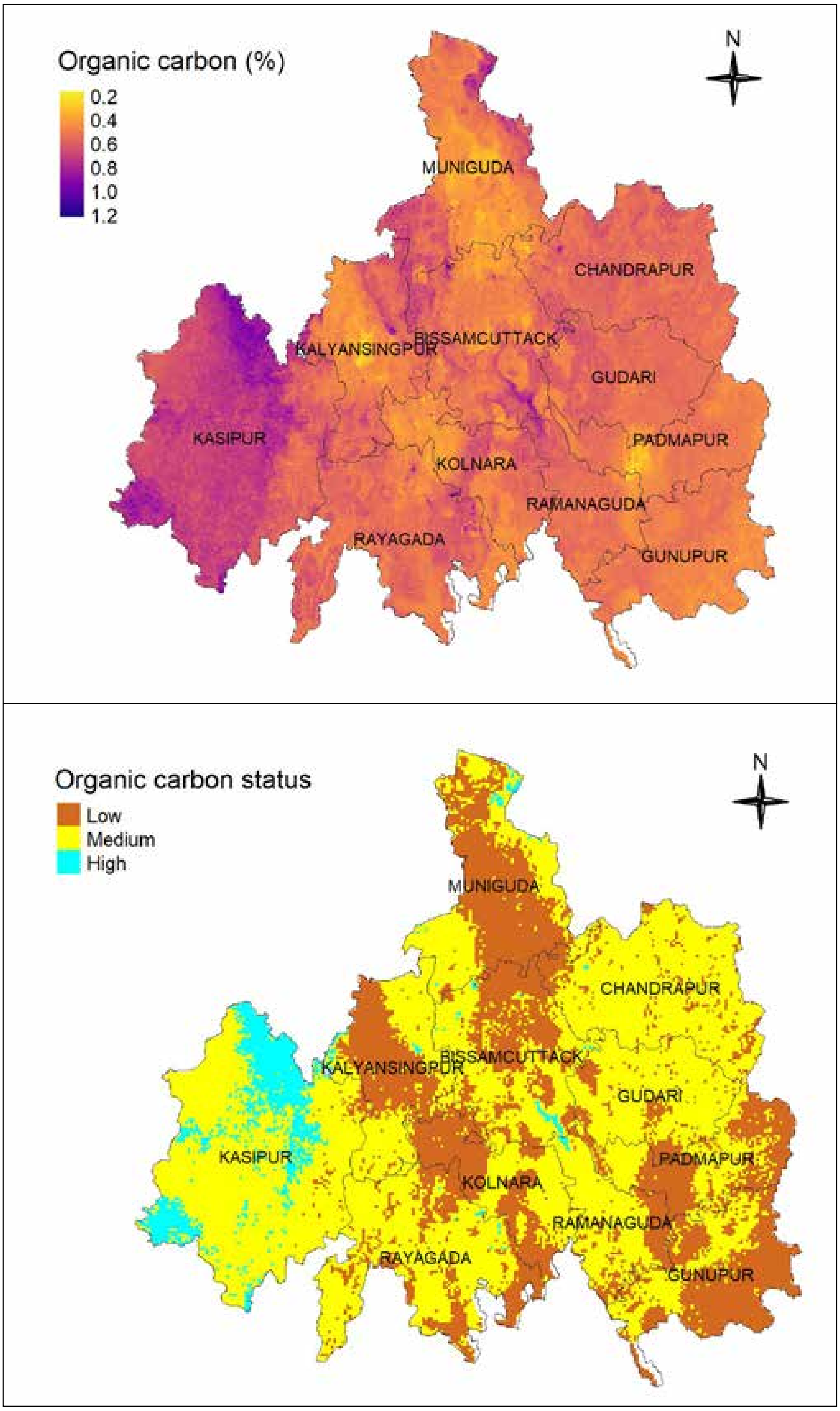


Figure 5.236. Organic carbon status in soils of Rayagada district.

Available Phosphorous

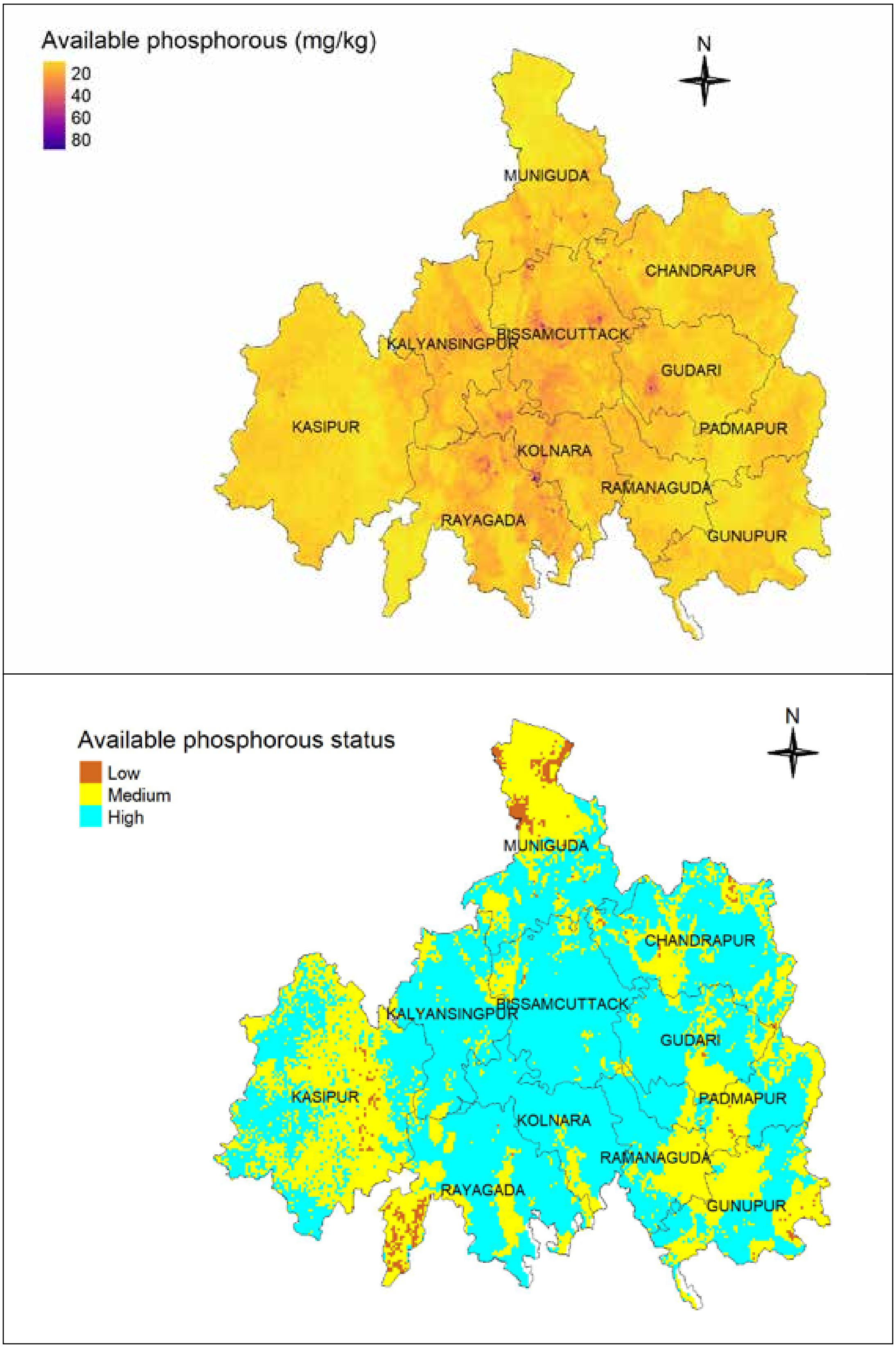
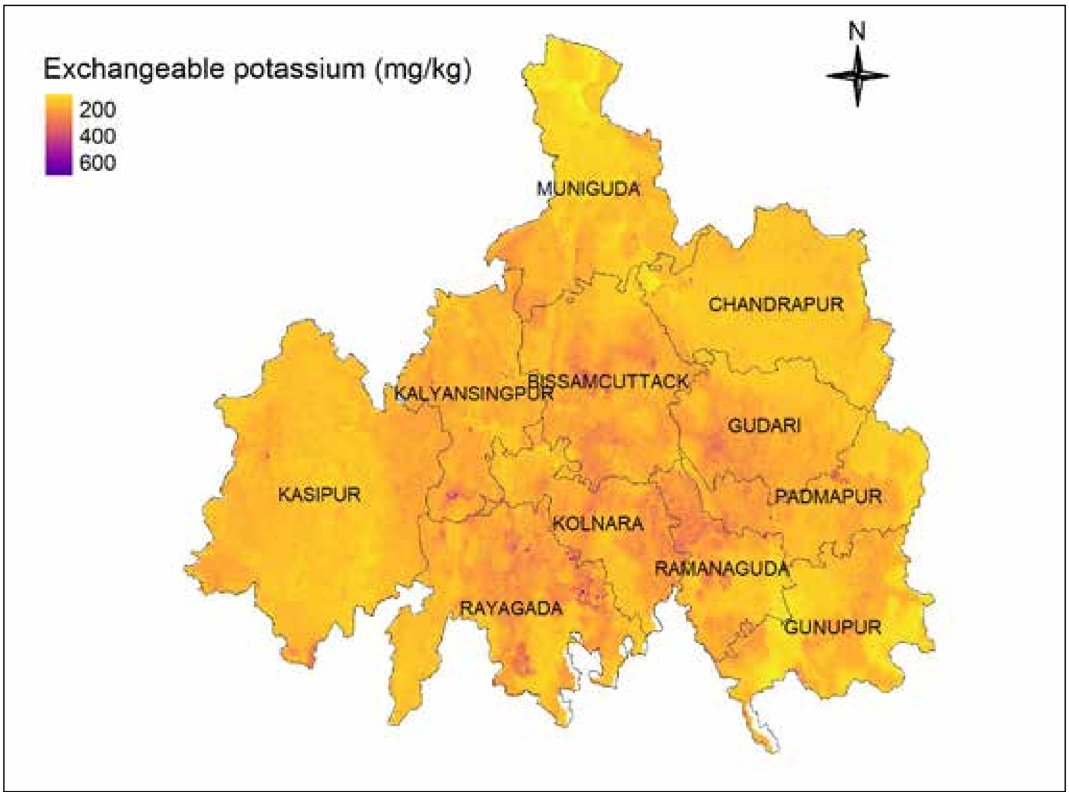


Figure 5.237. Status of available phosphorous in soils of Rayagada district.

Exchangeable Potassium



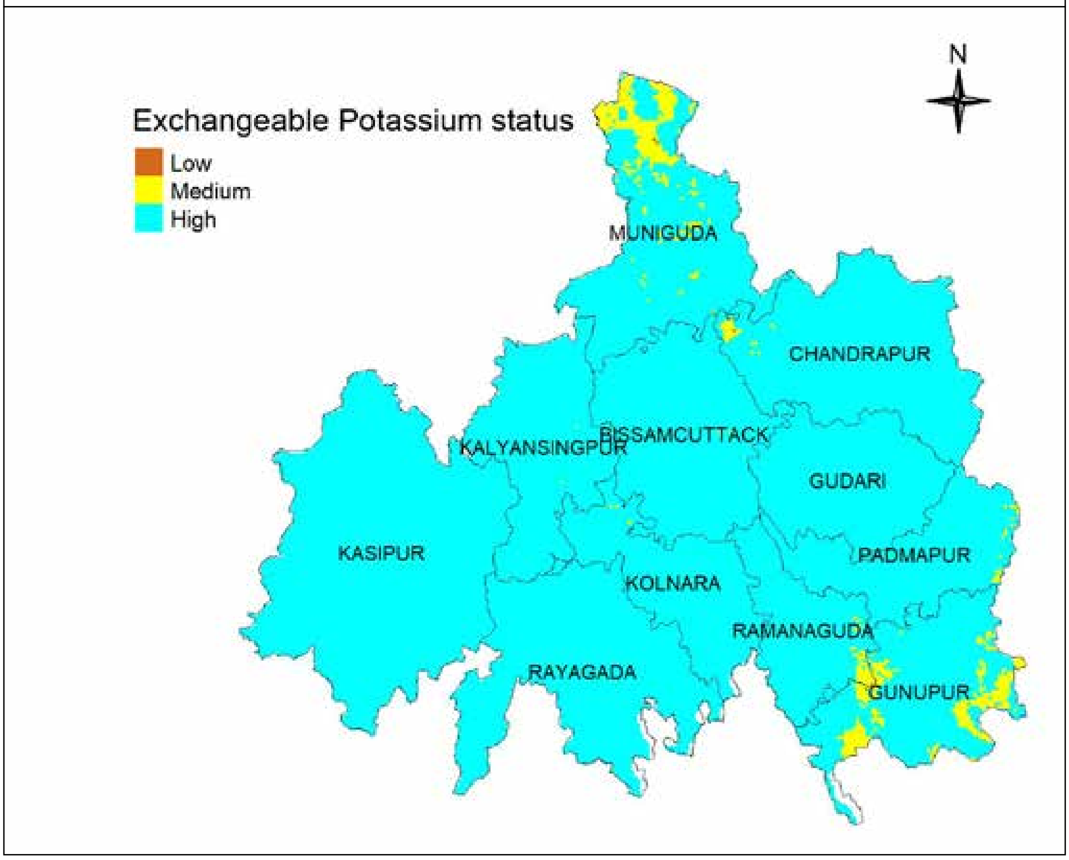


Figure 5.238. Status of exchangeable potassium in soils of Rayagada district.

Available Sulfur

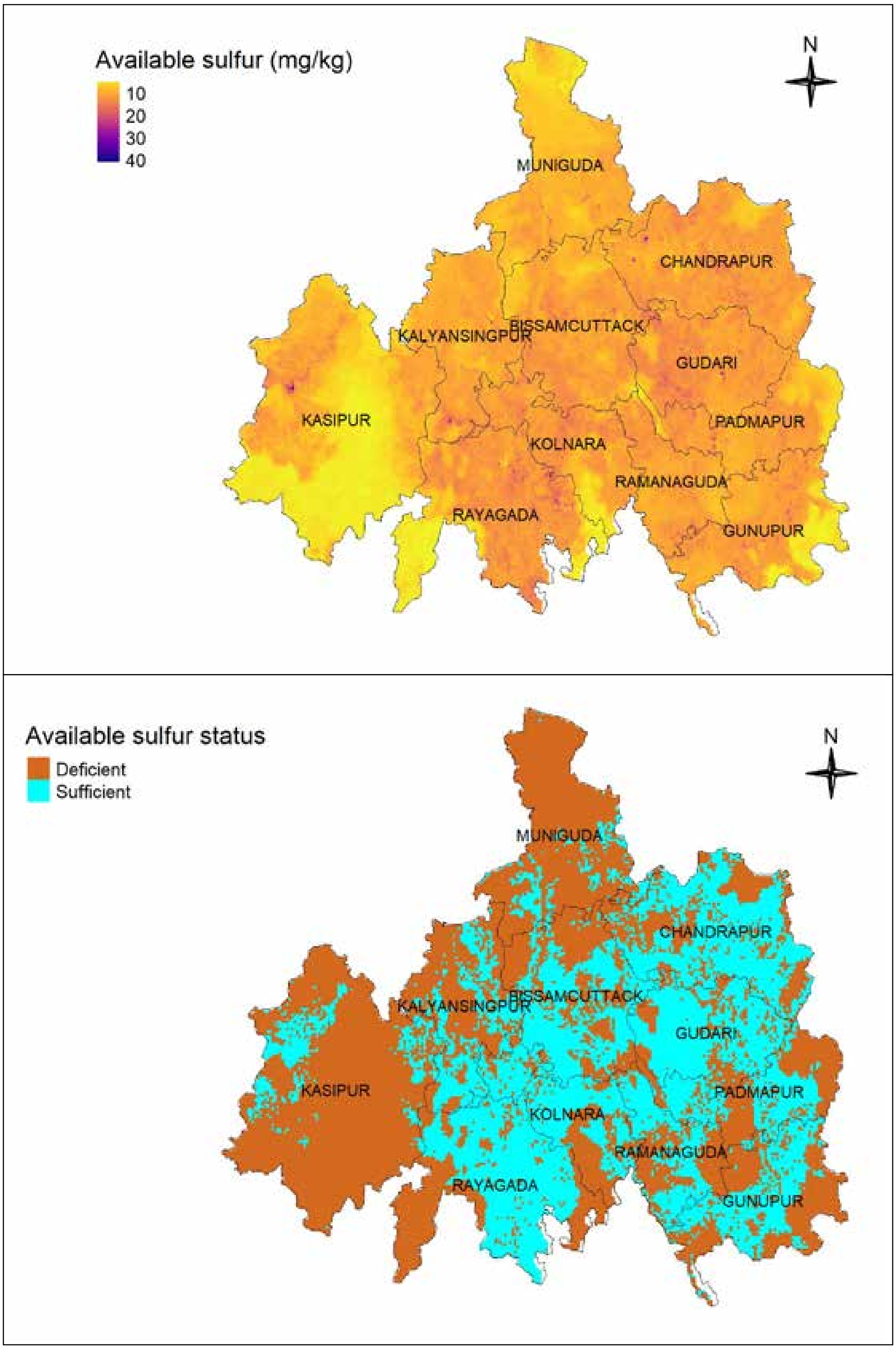


Figure 5.239. Status of available sulfur in soils of Rayagada district.

Available Boron

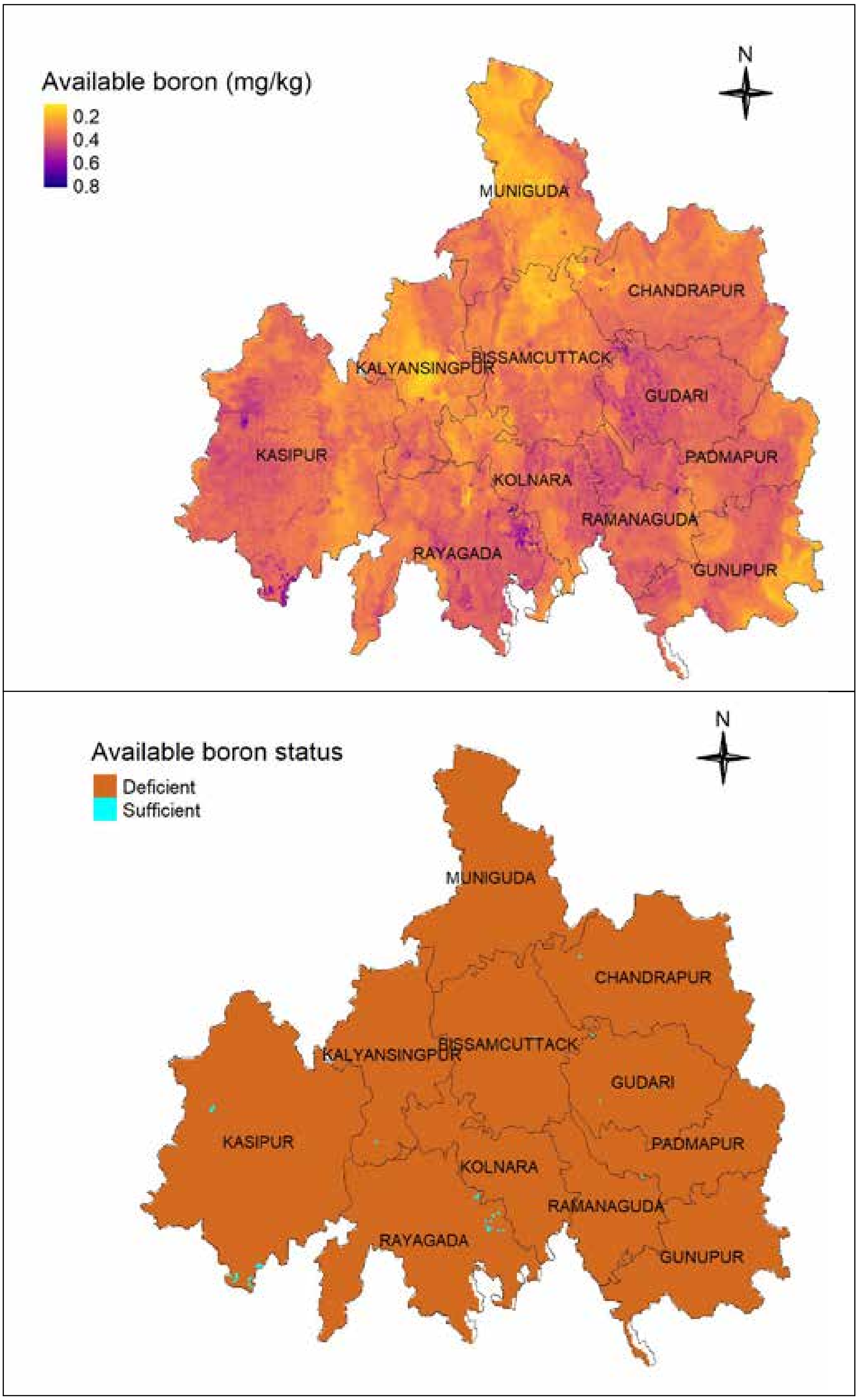


Figure 5.240. Status of available boron in soils of Rayagada district.

Available Zinc

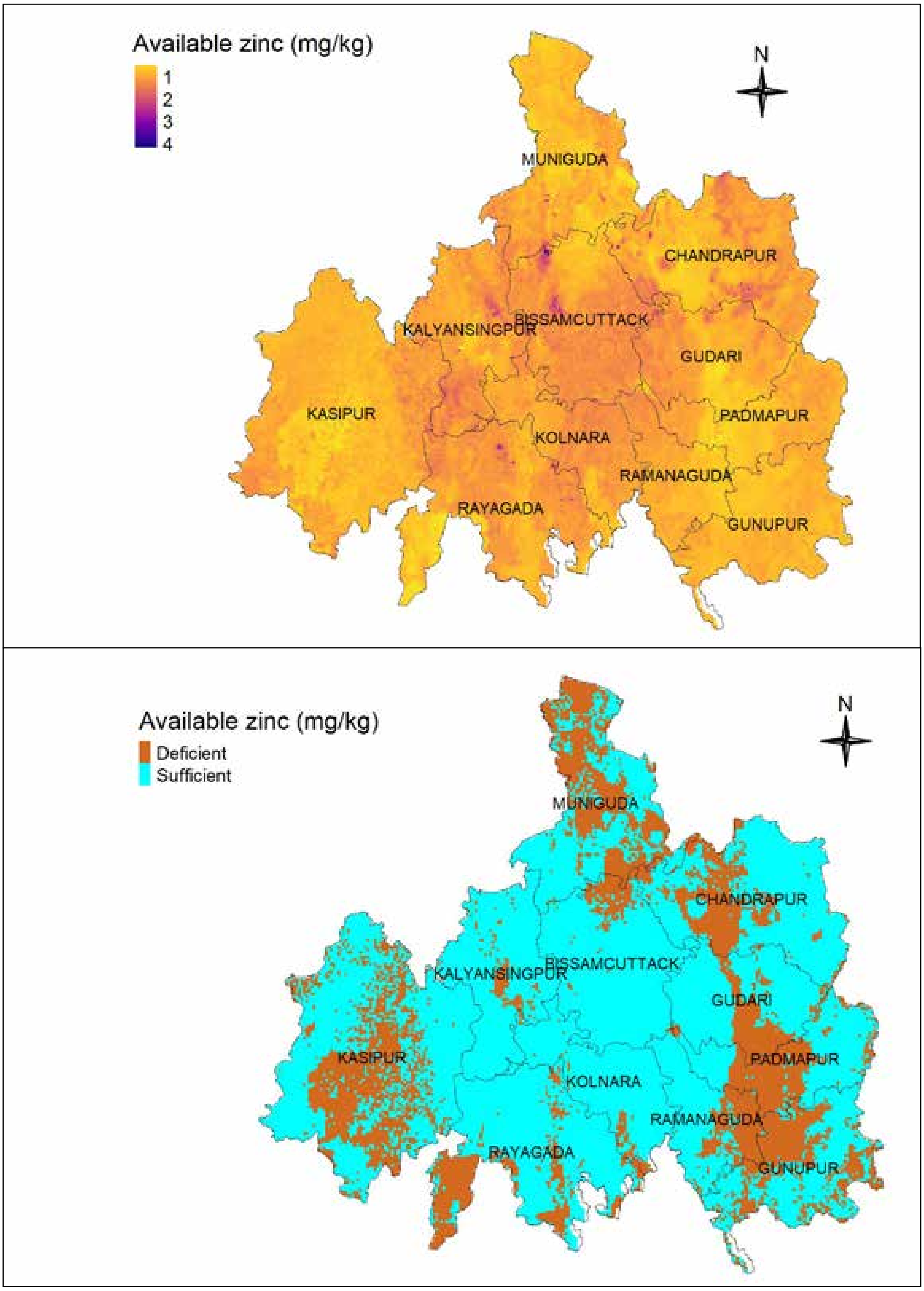


Figure 5.241. Status of available zinc in soils of Rayagada district.

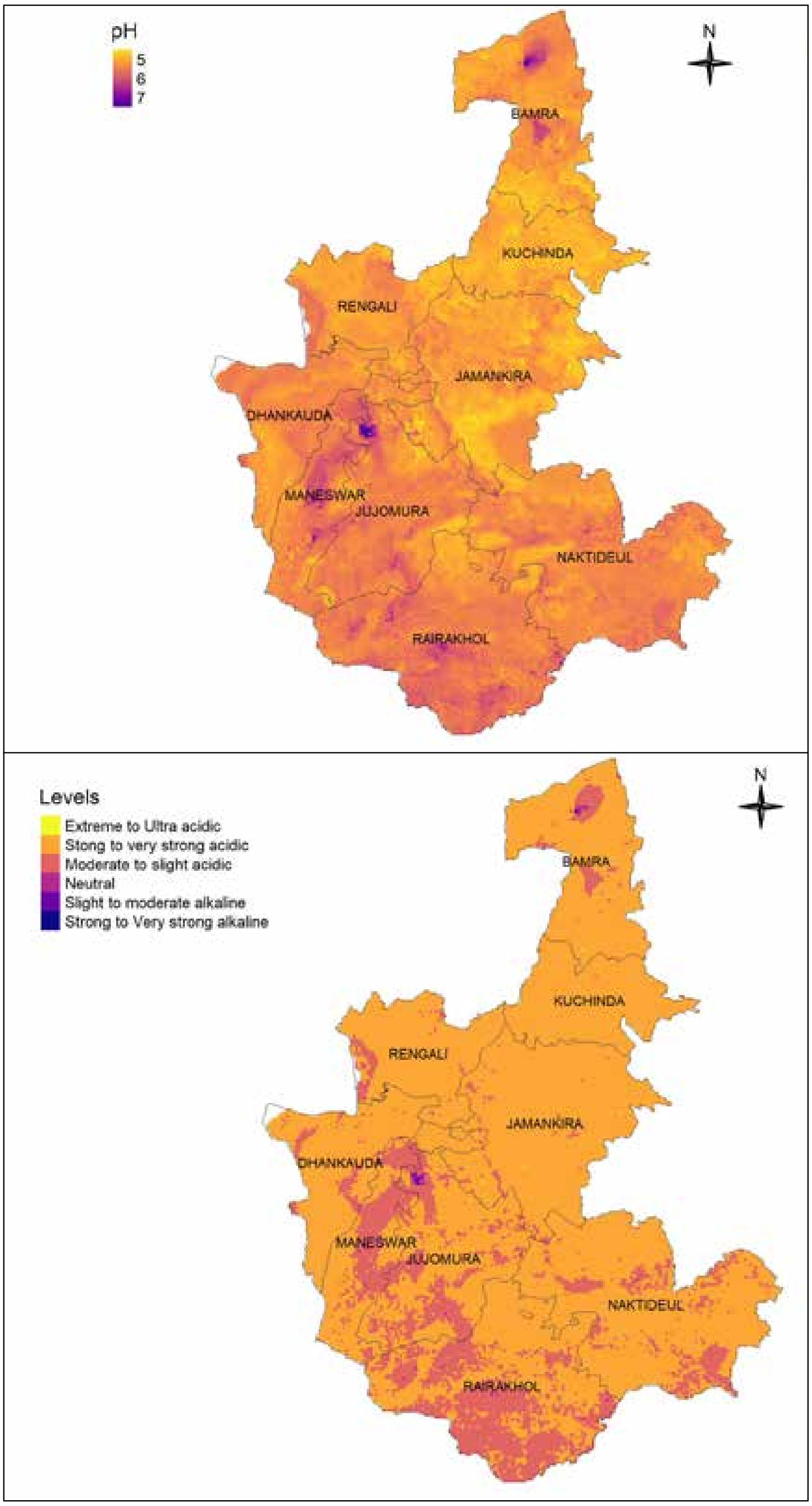


Figure 5.242. pH status in soils of Sambalpur district.

Electrical conductivity

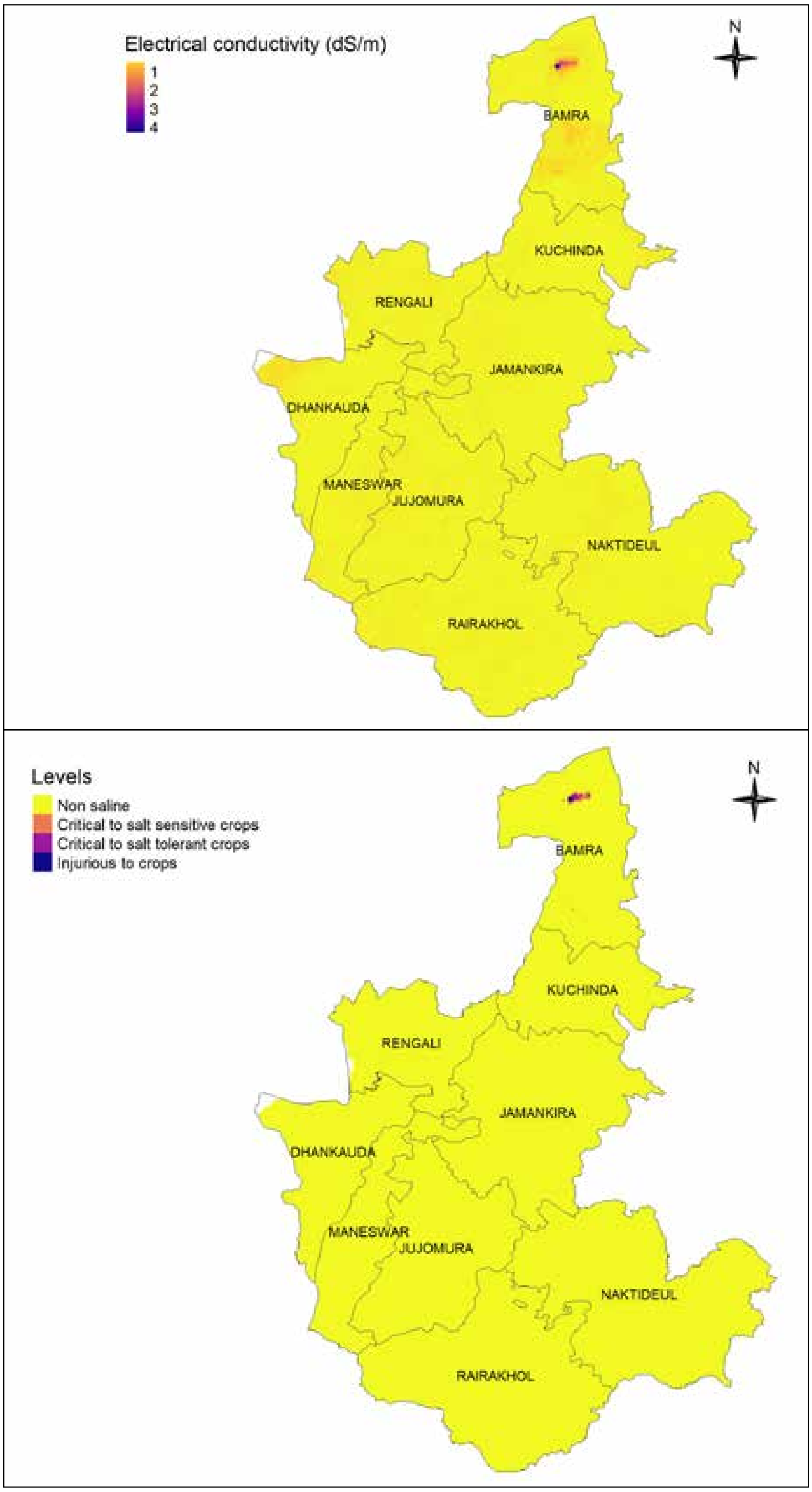


Figure 5.243. Status of electrical conductivity in soils of Sambalpur district.

Organic carbon

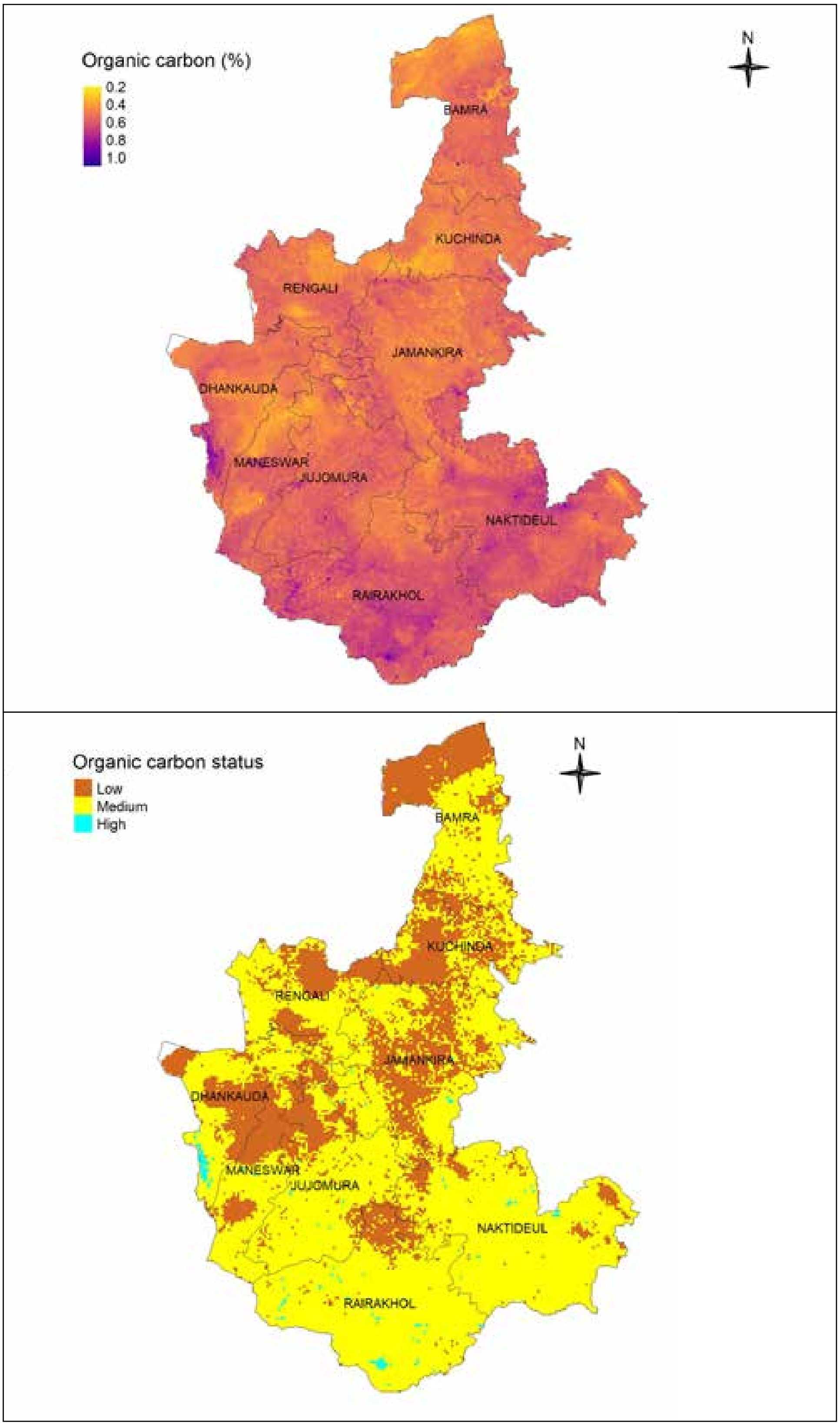


Figure 5.244. Organic carbon status in soils of Sambalpur district.

Available Phosphorous

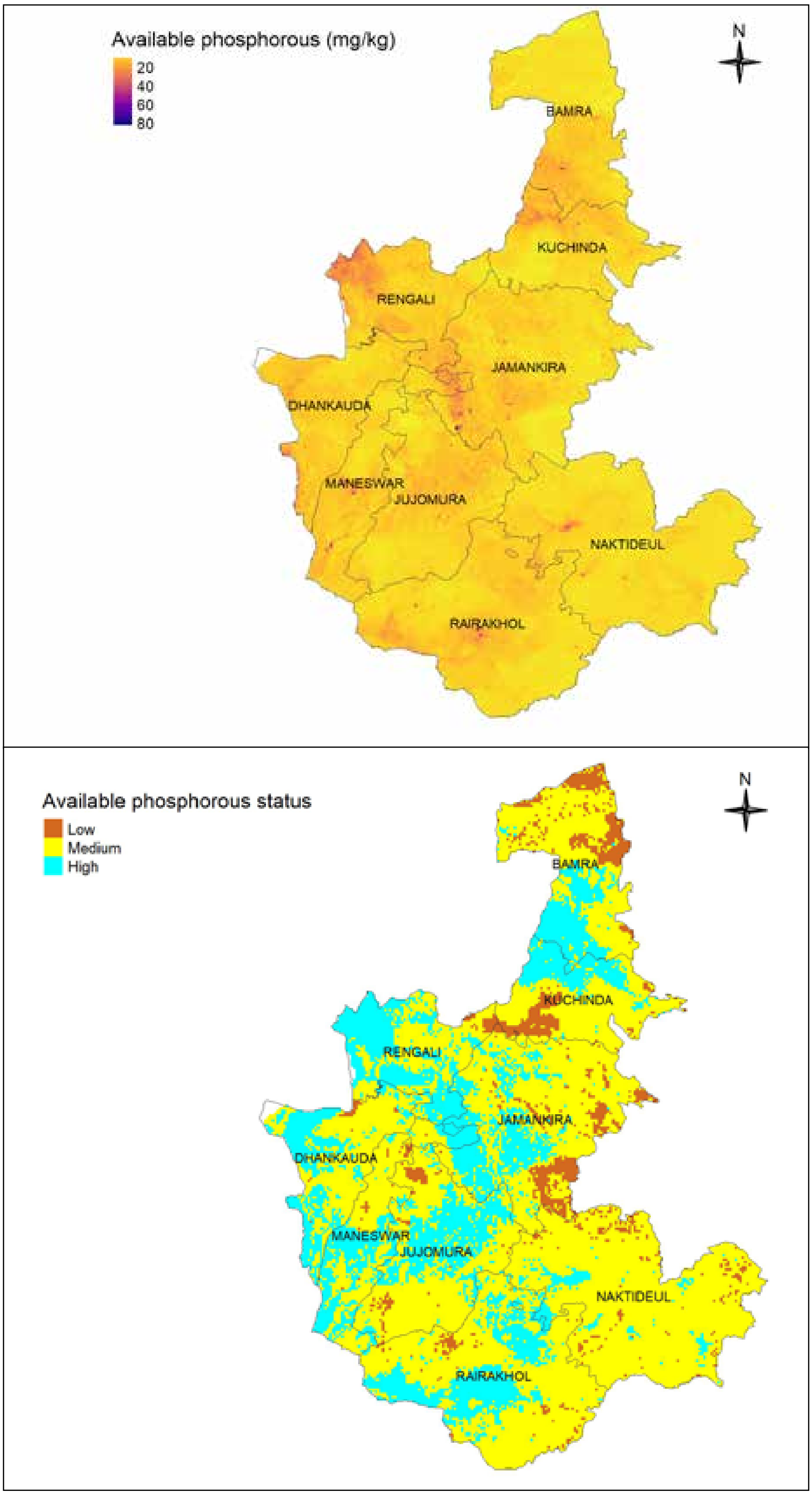


Figure 5.245. Status of available phosphorous in soils of Sambalpur district.

Exchangeable Potassium

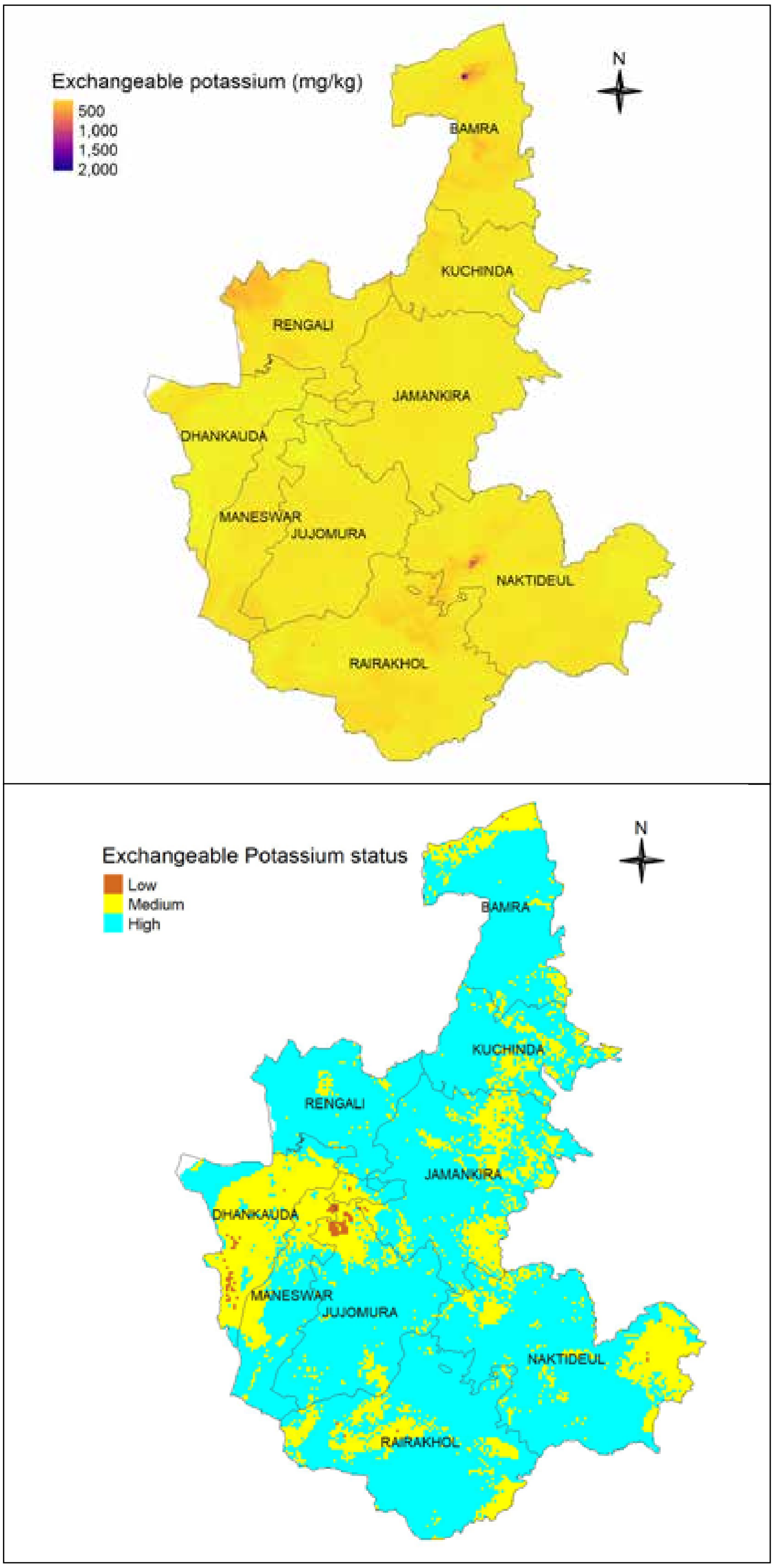


Figure 5.246. Status of exchangeable potassium in soils of Sambalpur district.

Available Sulfur

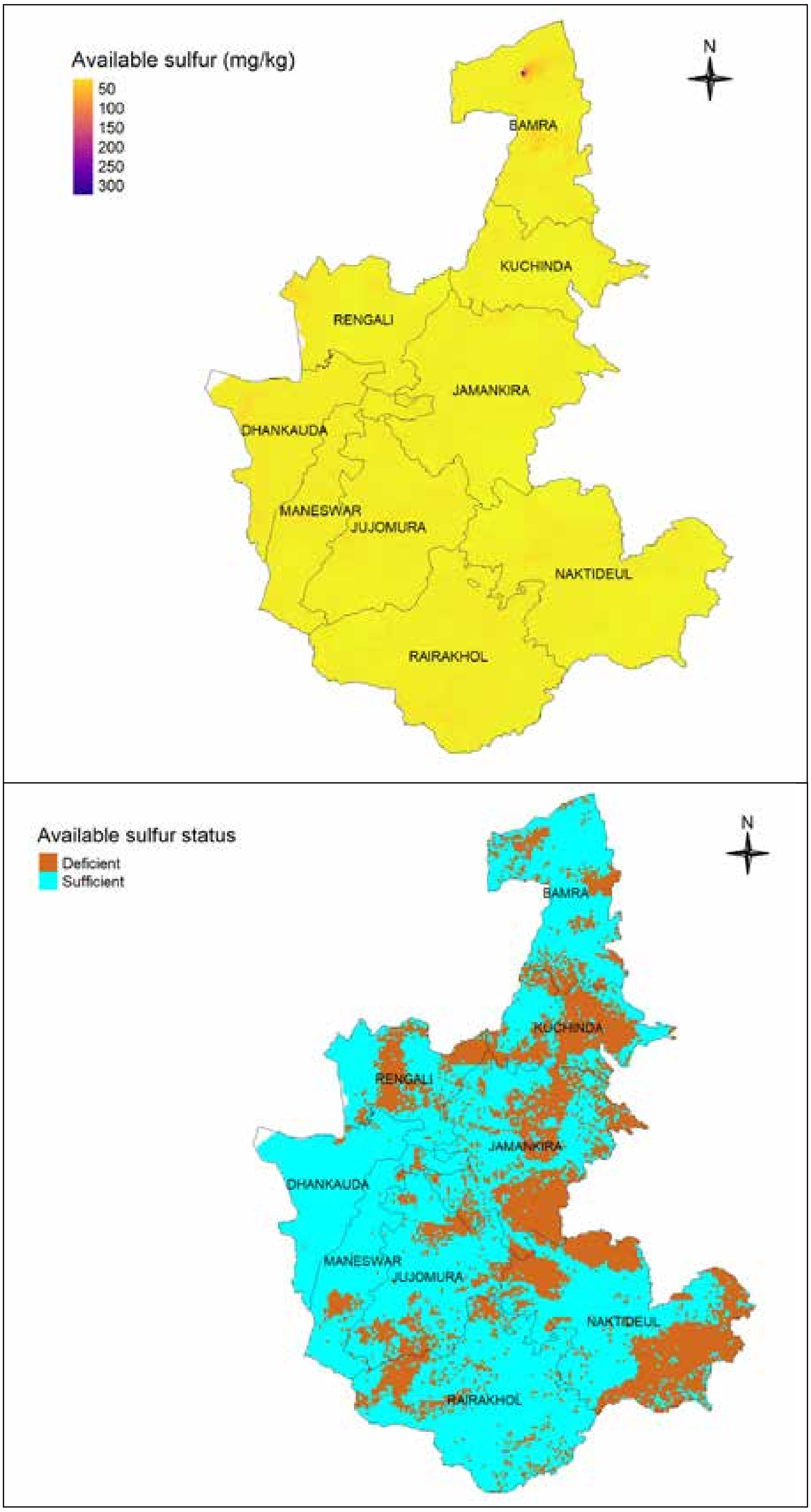


Figure 5.247. Status of available sulfur in soils of Sambalpur district.

Available Boron

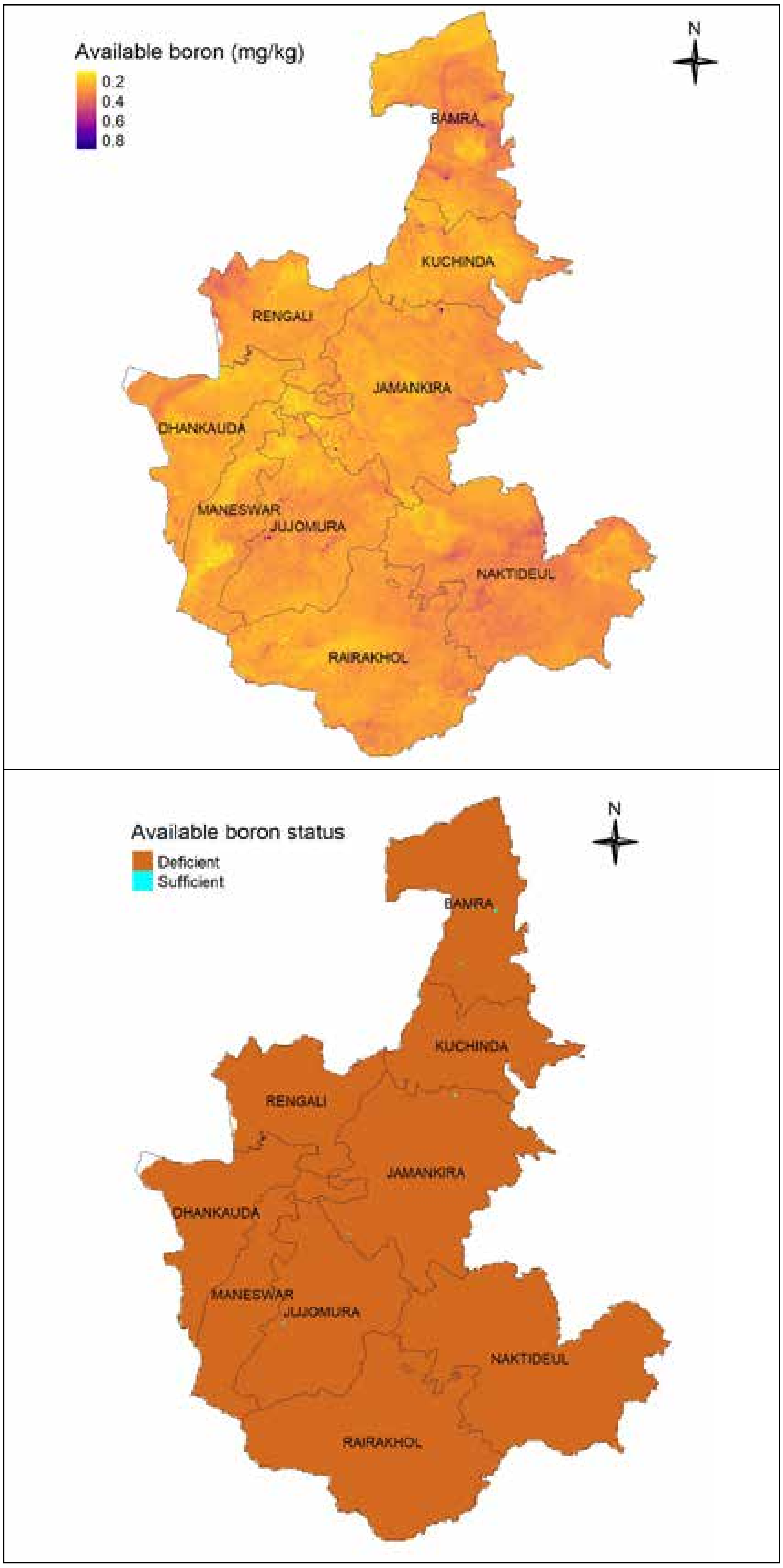


Figure 5.248. Status of available boron in soils of Sambalpur district.

Available Zinc

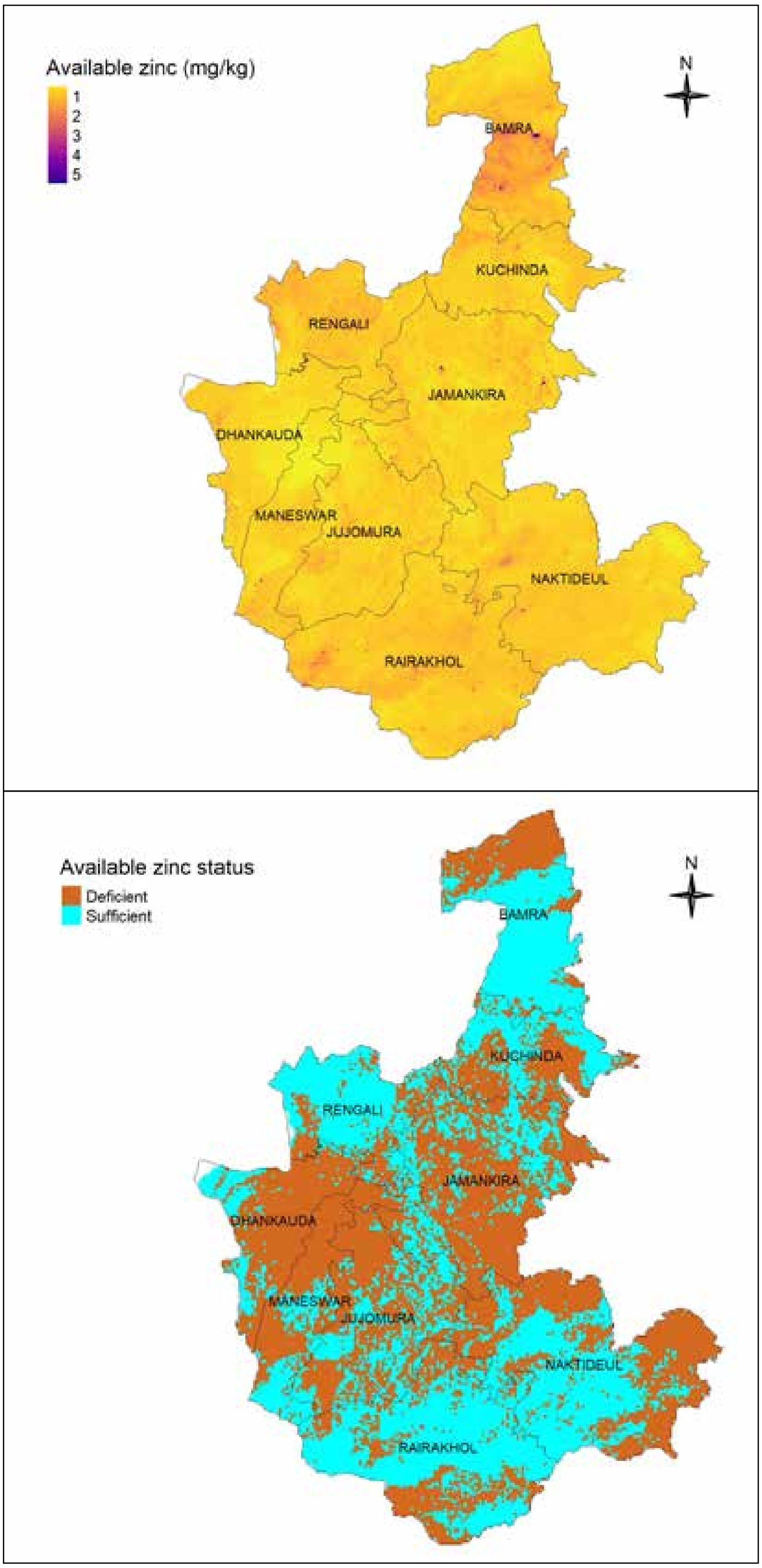


Figure 5.249. Status of available zinc in soils of Sambalpur district.

Subarnapur | pH

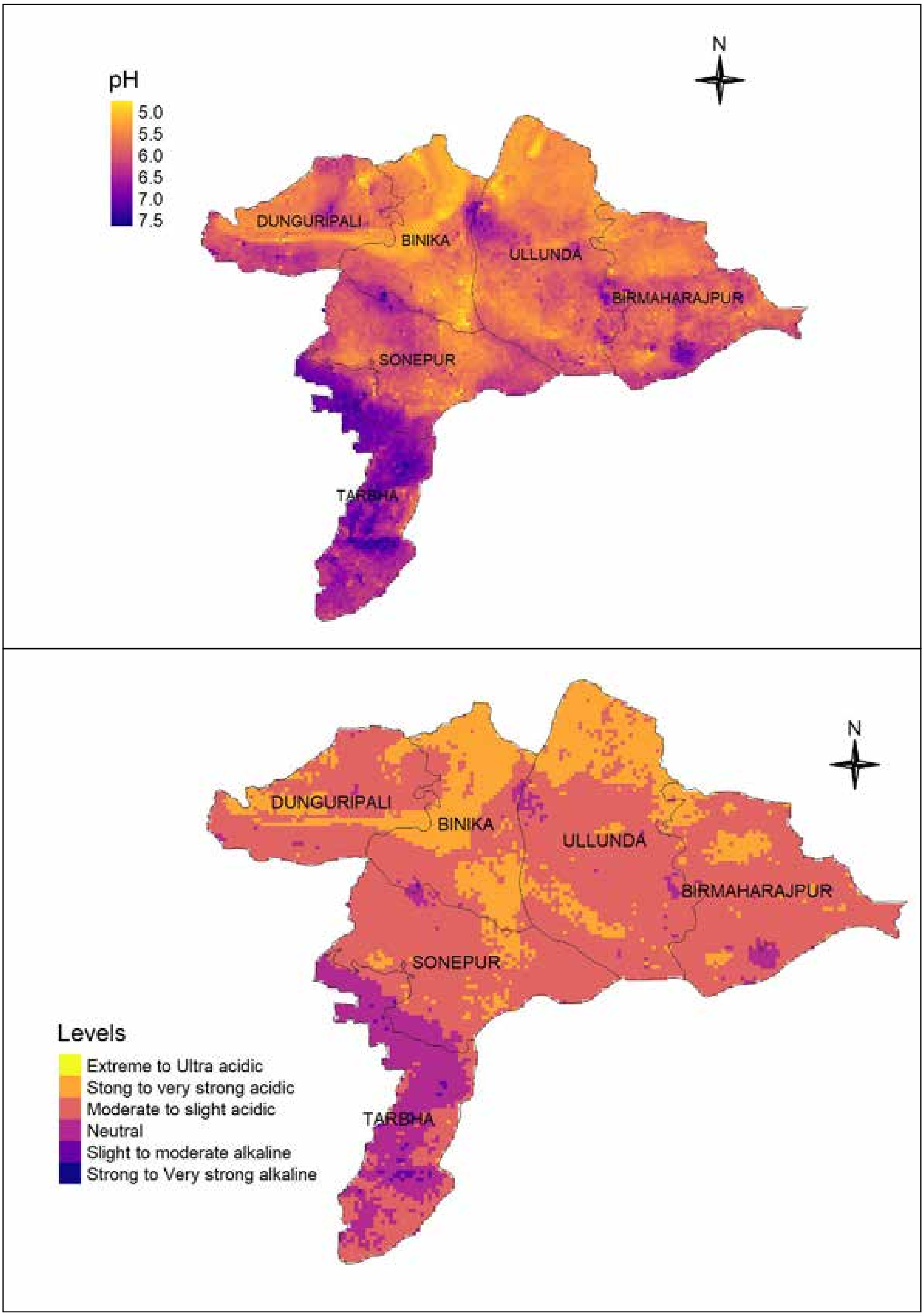


Figure 5.250. pH status in soils of Subarnapur district.

Electrical conductivity

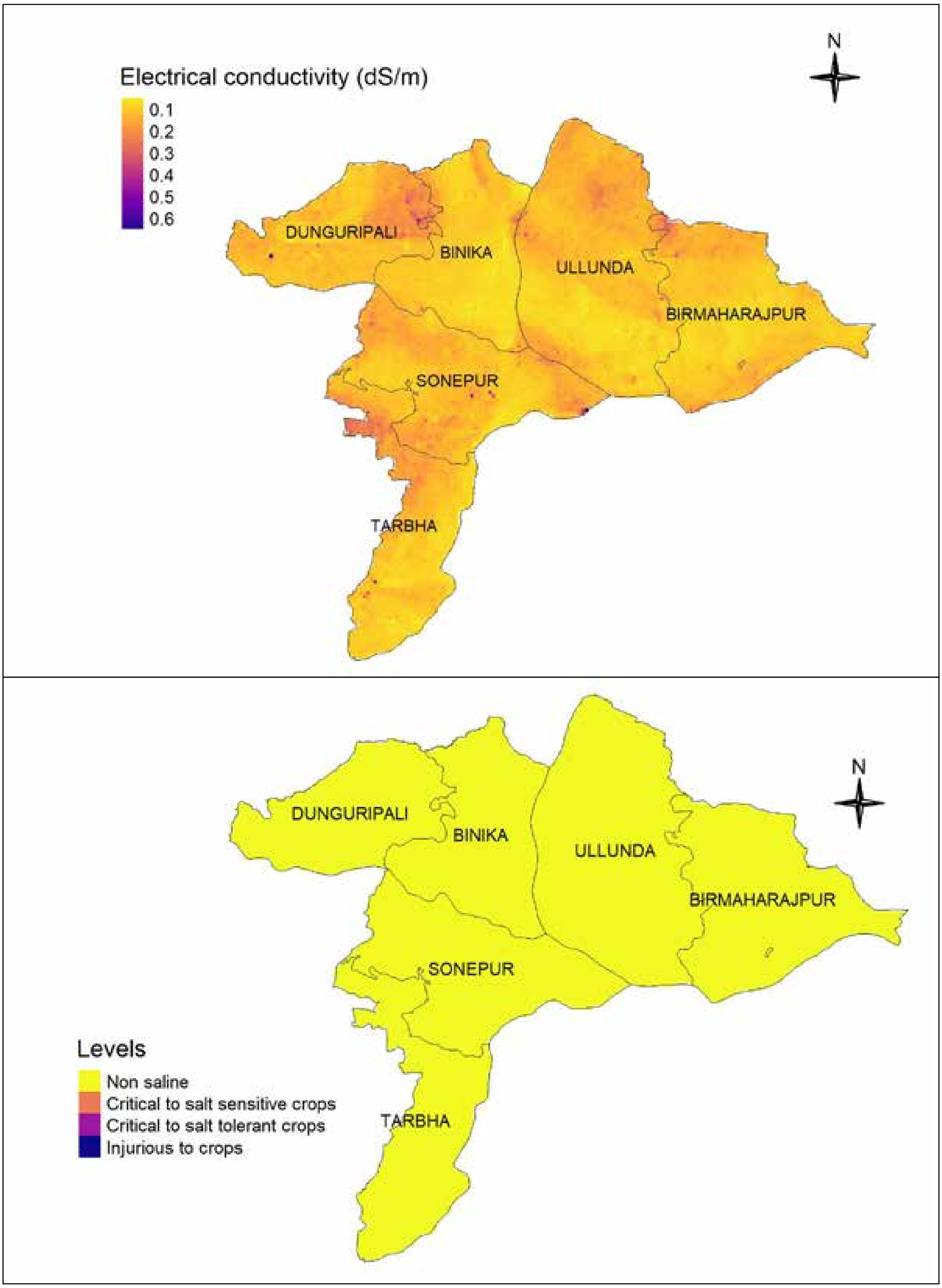


Figure 5.251. Status of electrical conductivity in soils of Subarnapur district.

Organic carbon

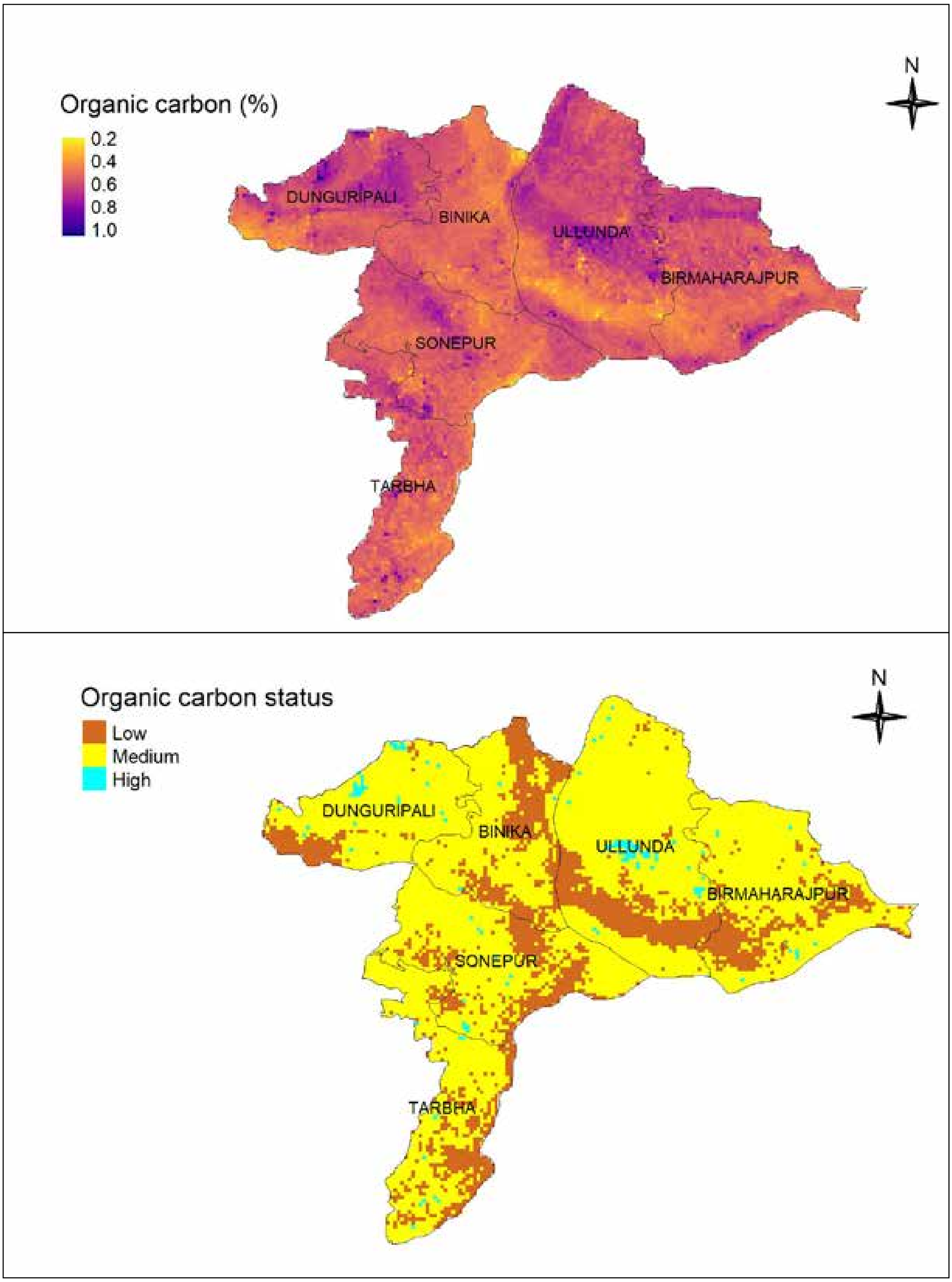


Figure 5.252. Organic carbon status in soils of Subarnapur district.

Available Phosphorous

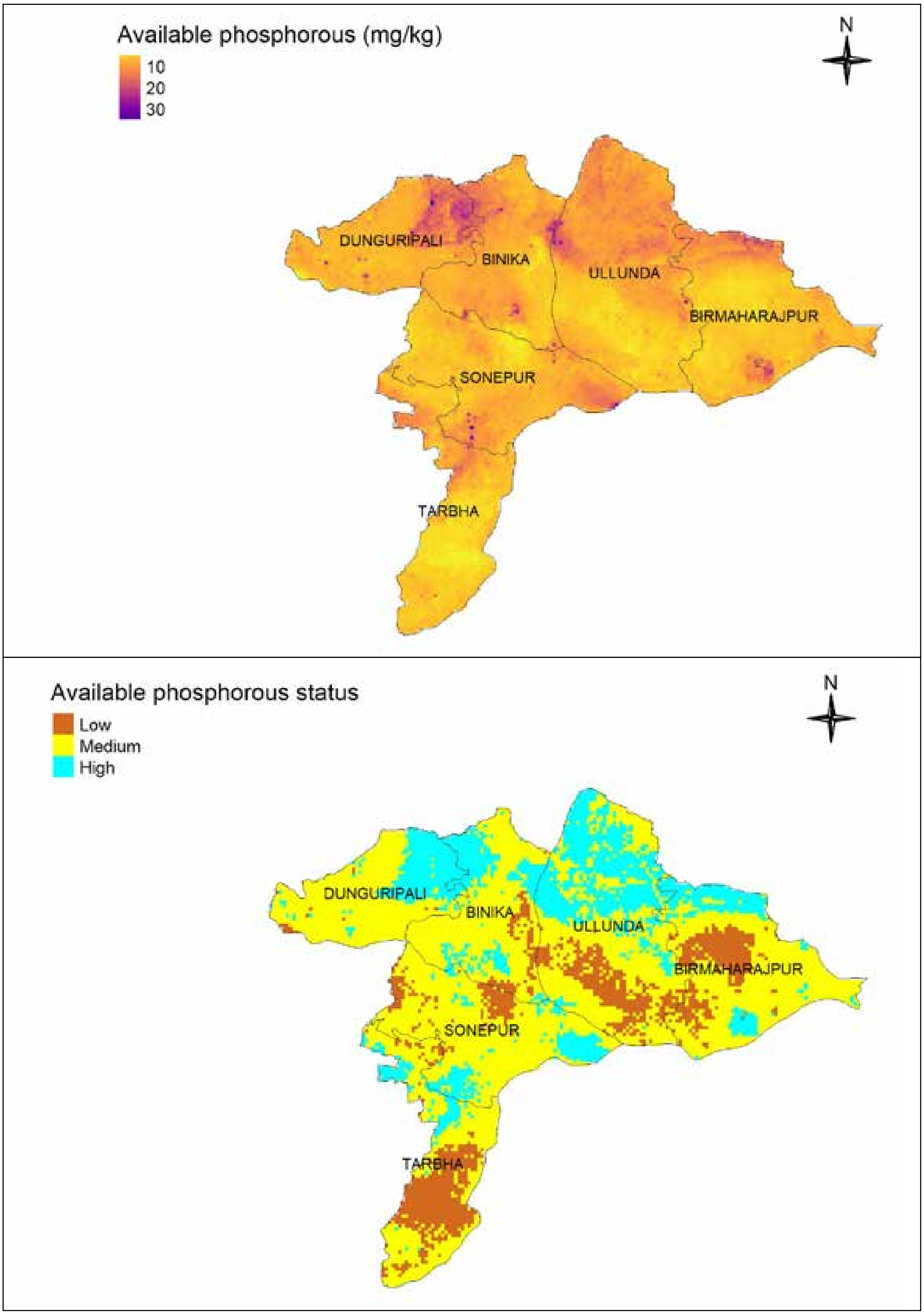


Figure 5.253. Status of available phosphorous in soils of Subarnapur district.

Exchangeable Potassium

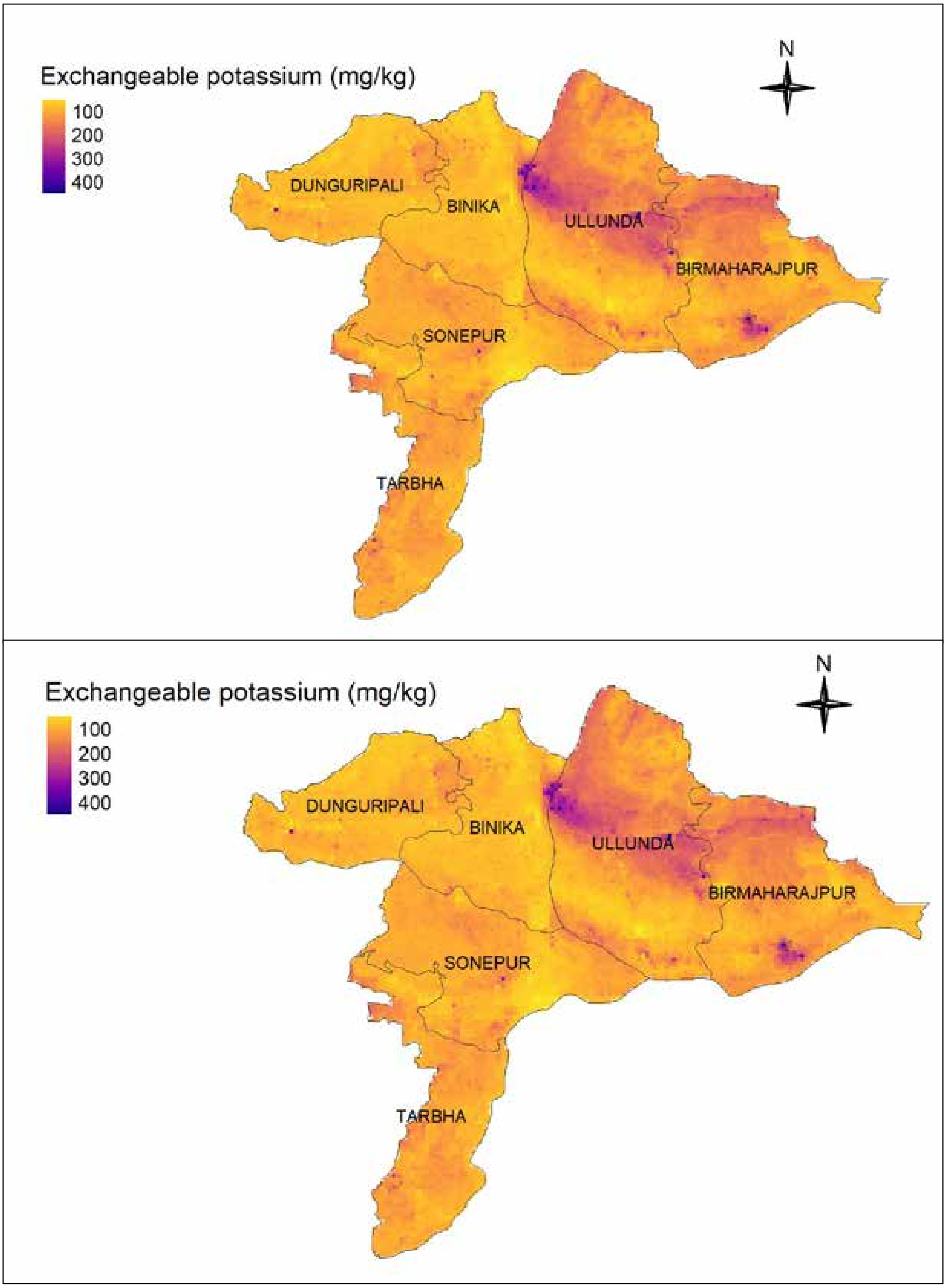


Figure 5.254. Status of exchangeable potassium in soils of Subarnapur district.

Available Sulfur

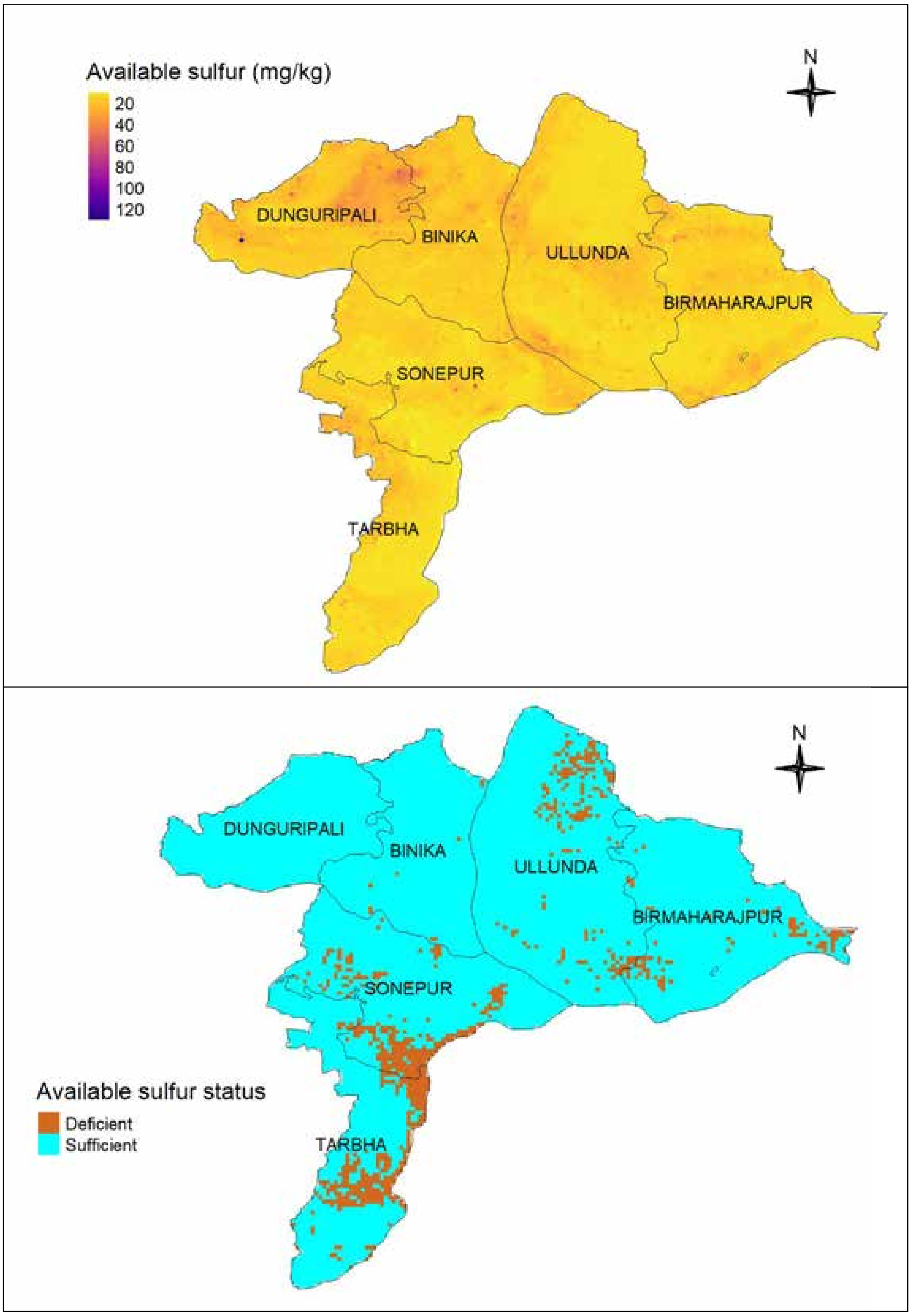


Figure 5.255. Status of available sulfur in soils of Subarnapur district.

Available Boron

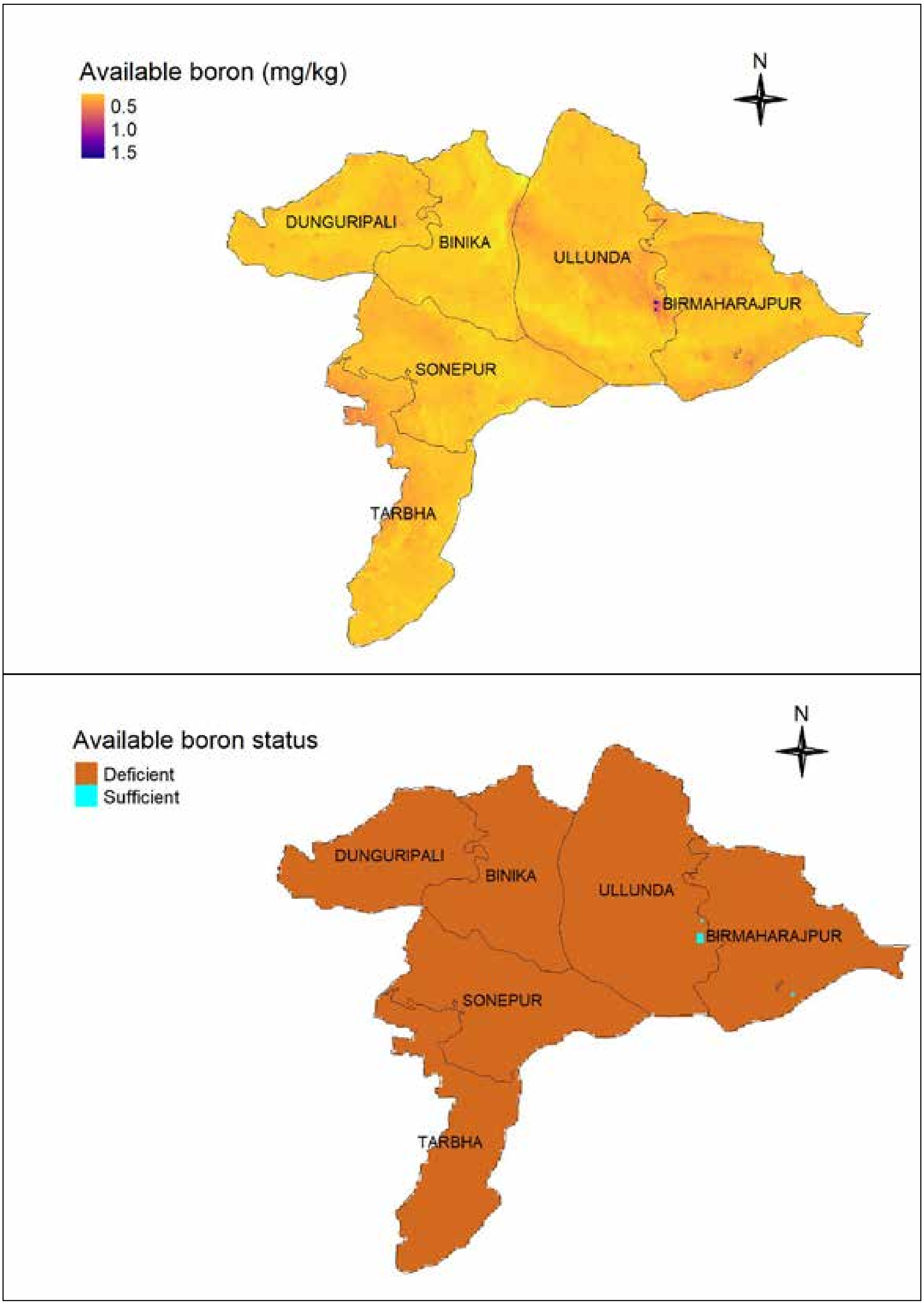


Figure 5.256. Status of available boron in soils of Subarnapur district.

Available Zinc

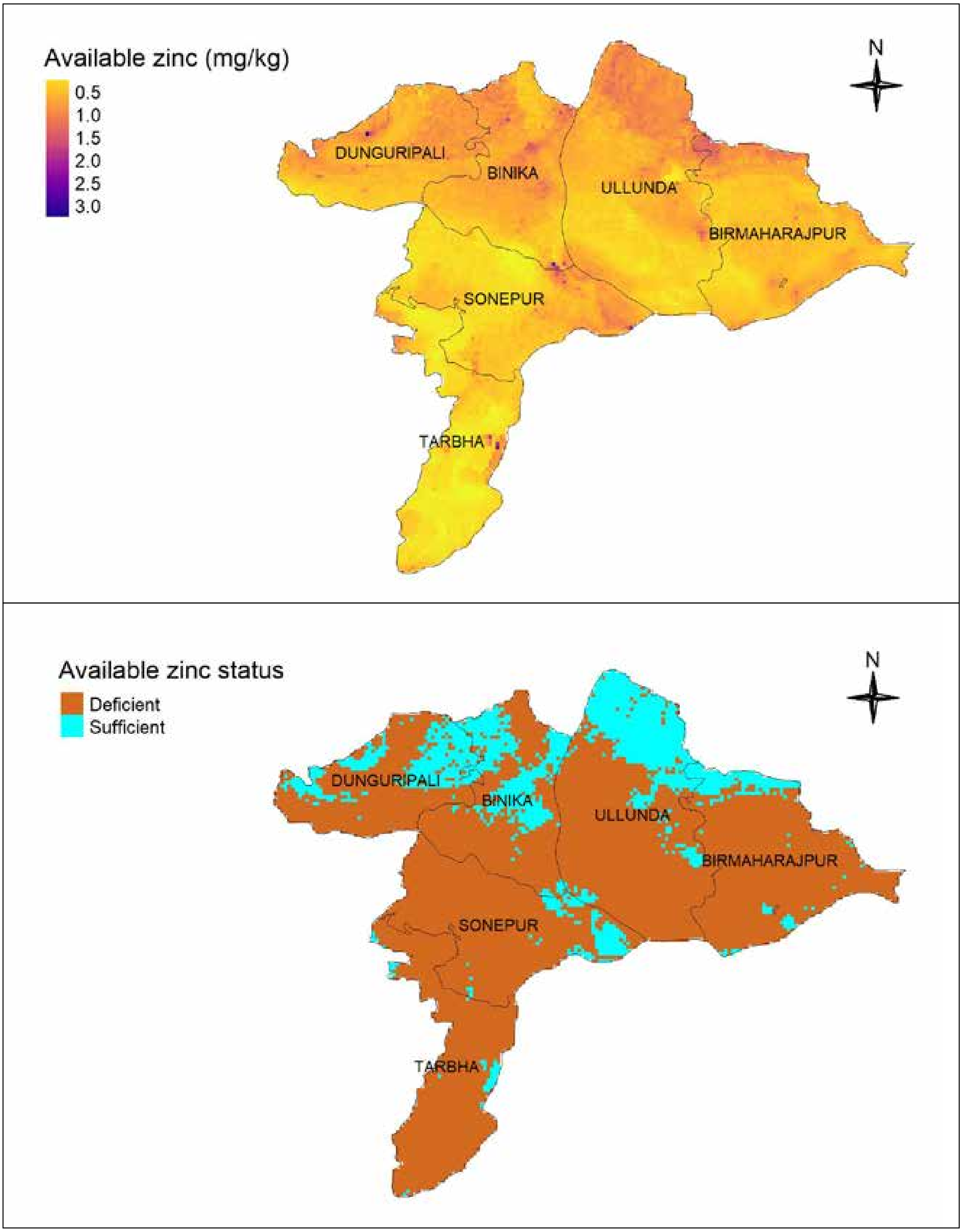


Figure 5.257. Status of available zinc in soils of Subarnapur district.

Sundargarh | pH

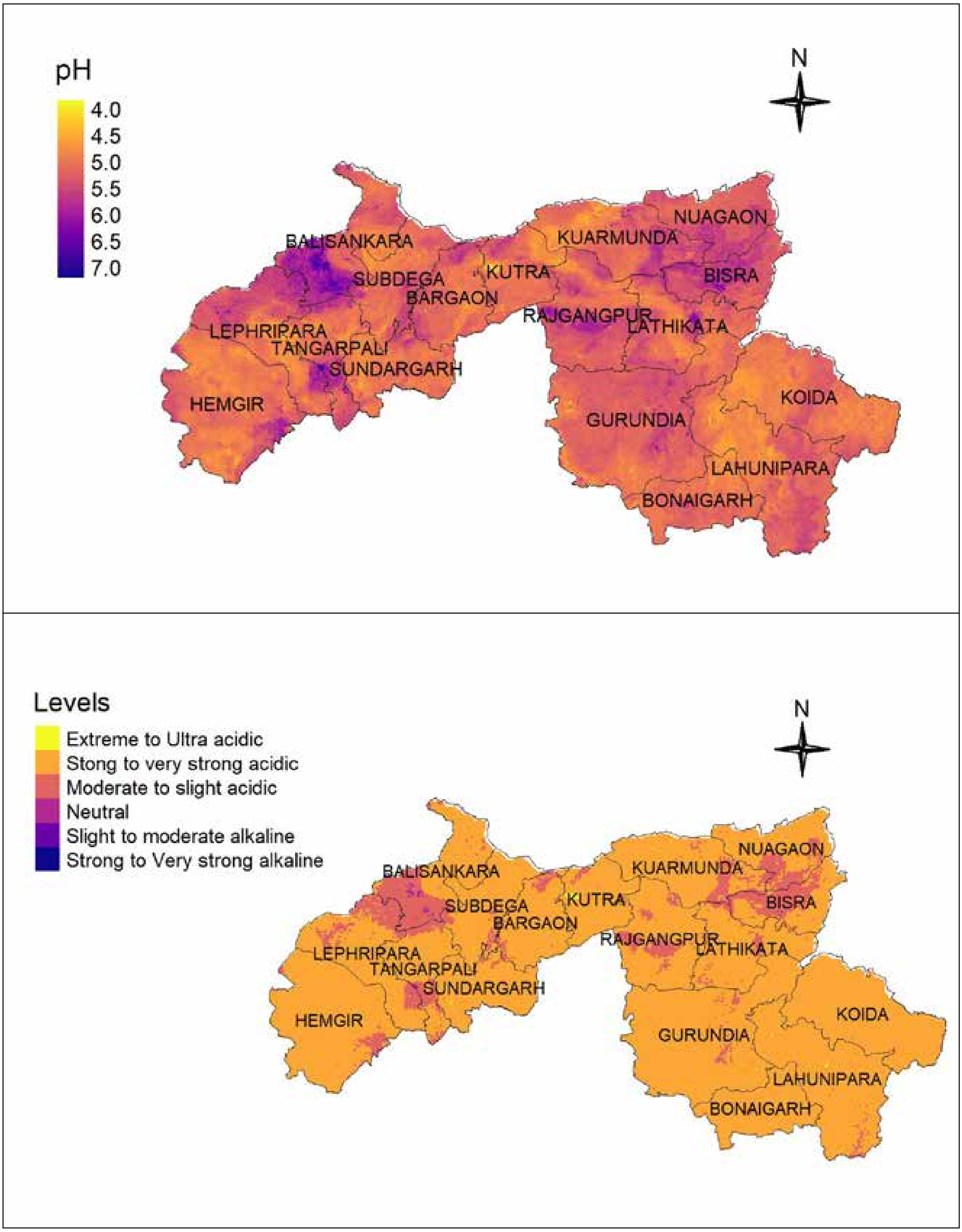


Figure 5.258. pH status in soils of Sundargarh district.

Electrical conductivity

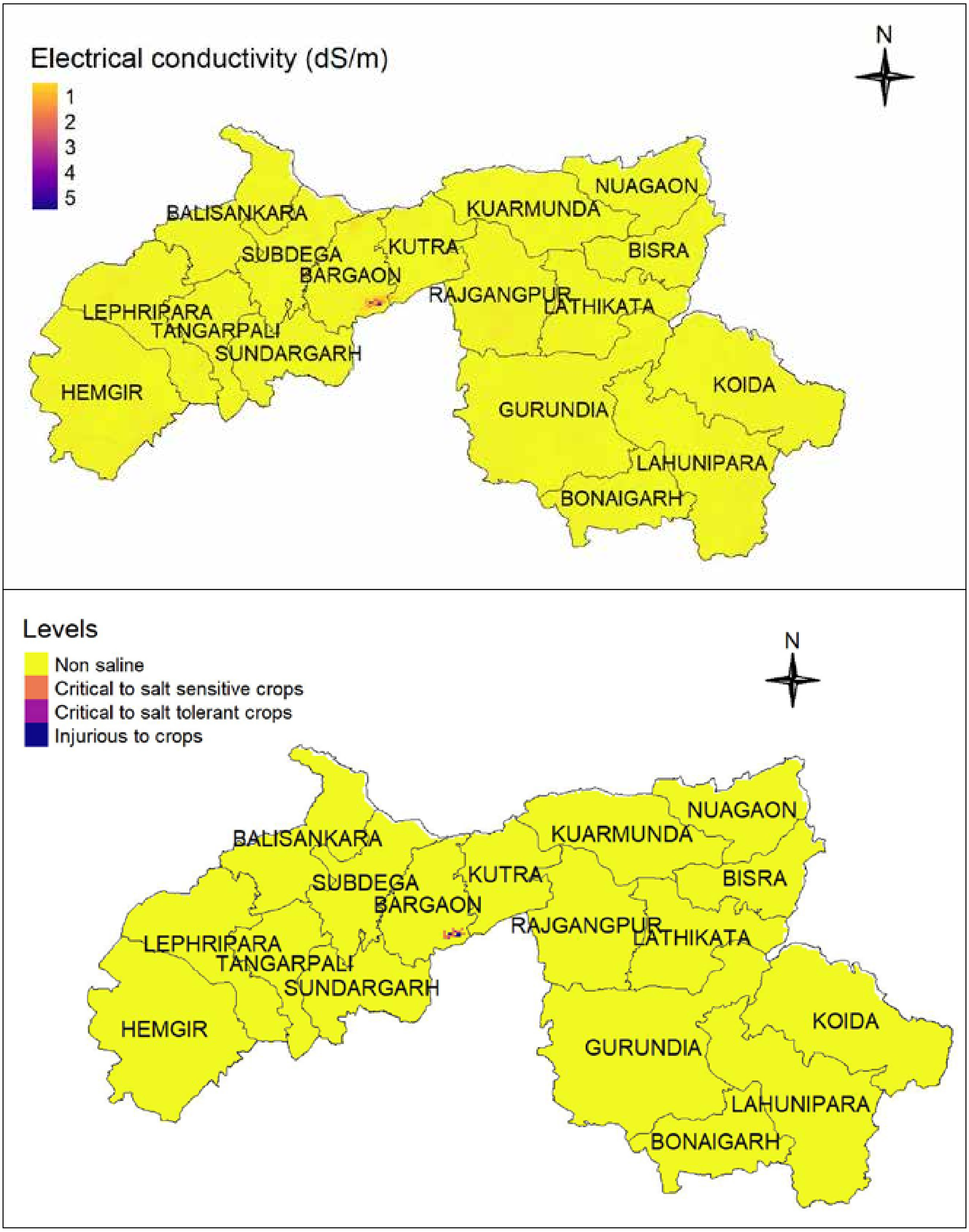


Figure 5.259. Status of electrical conductivity in soils of Sundargarh district.

Organic carbon

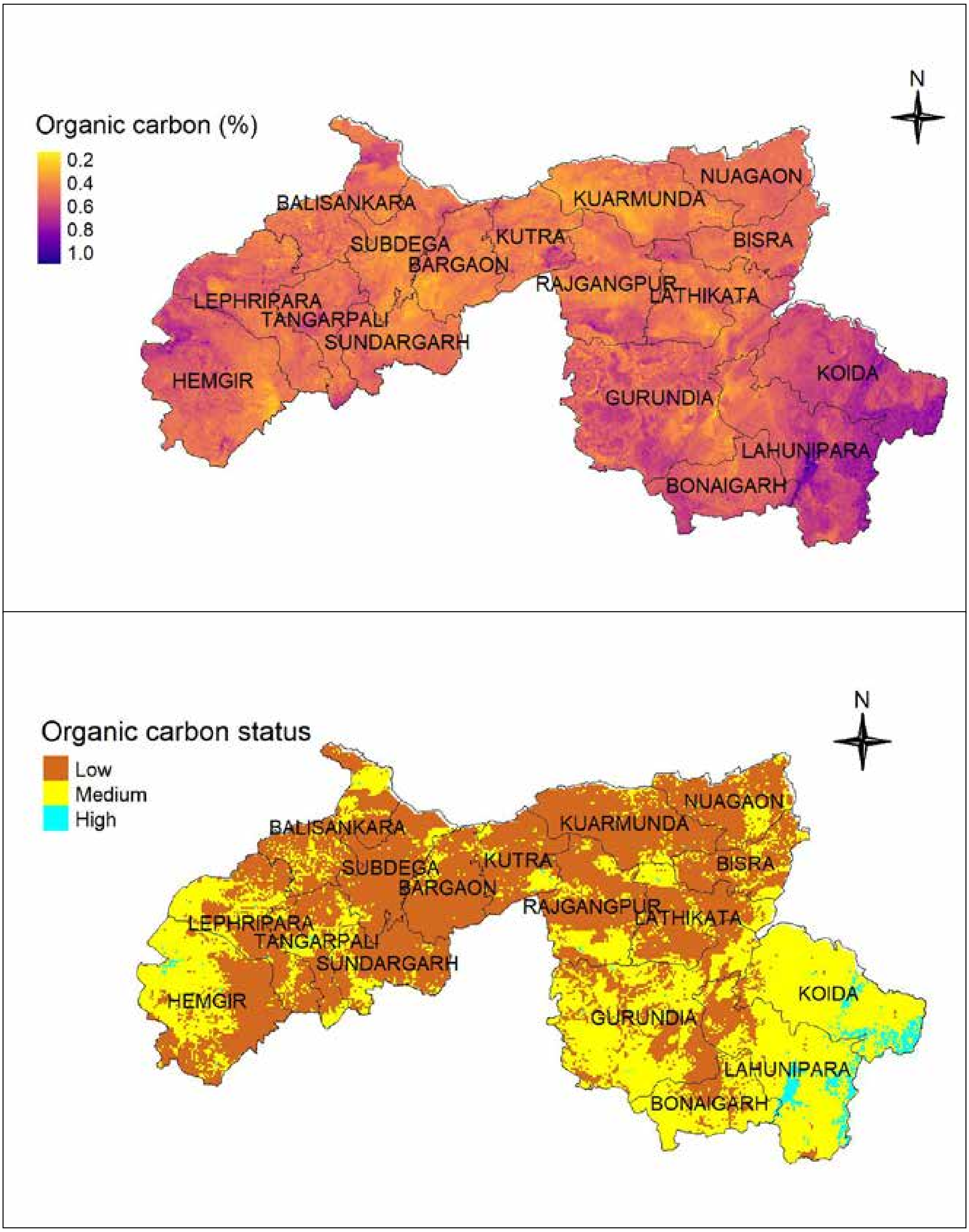


Figure 5.260. Organic carbon status in soils of Sundargarh district.

Available Phosphorous

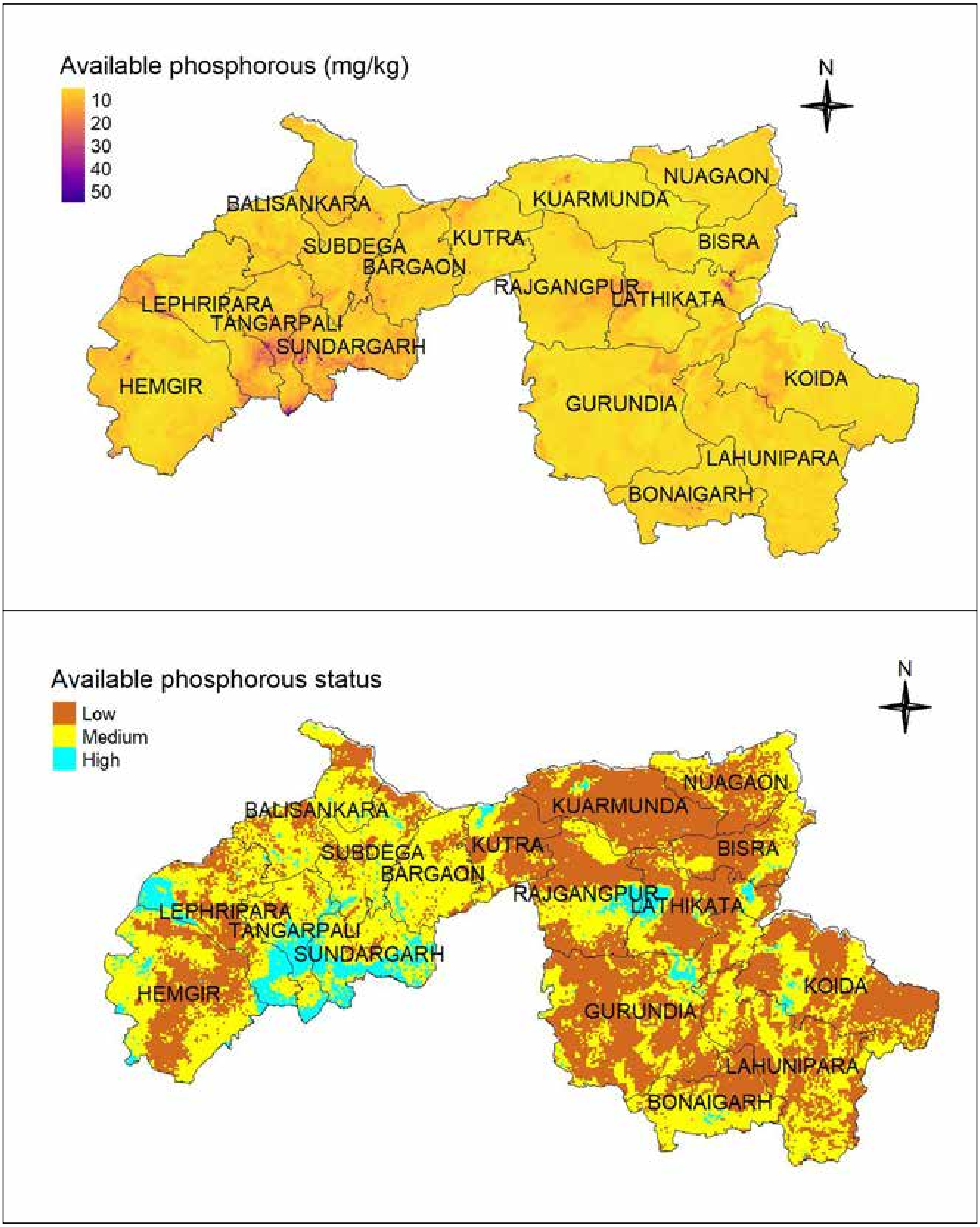


Figure 5.261. Status of available phosphorous in soils of Sundargarh district.

Exchangeable Potassium

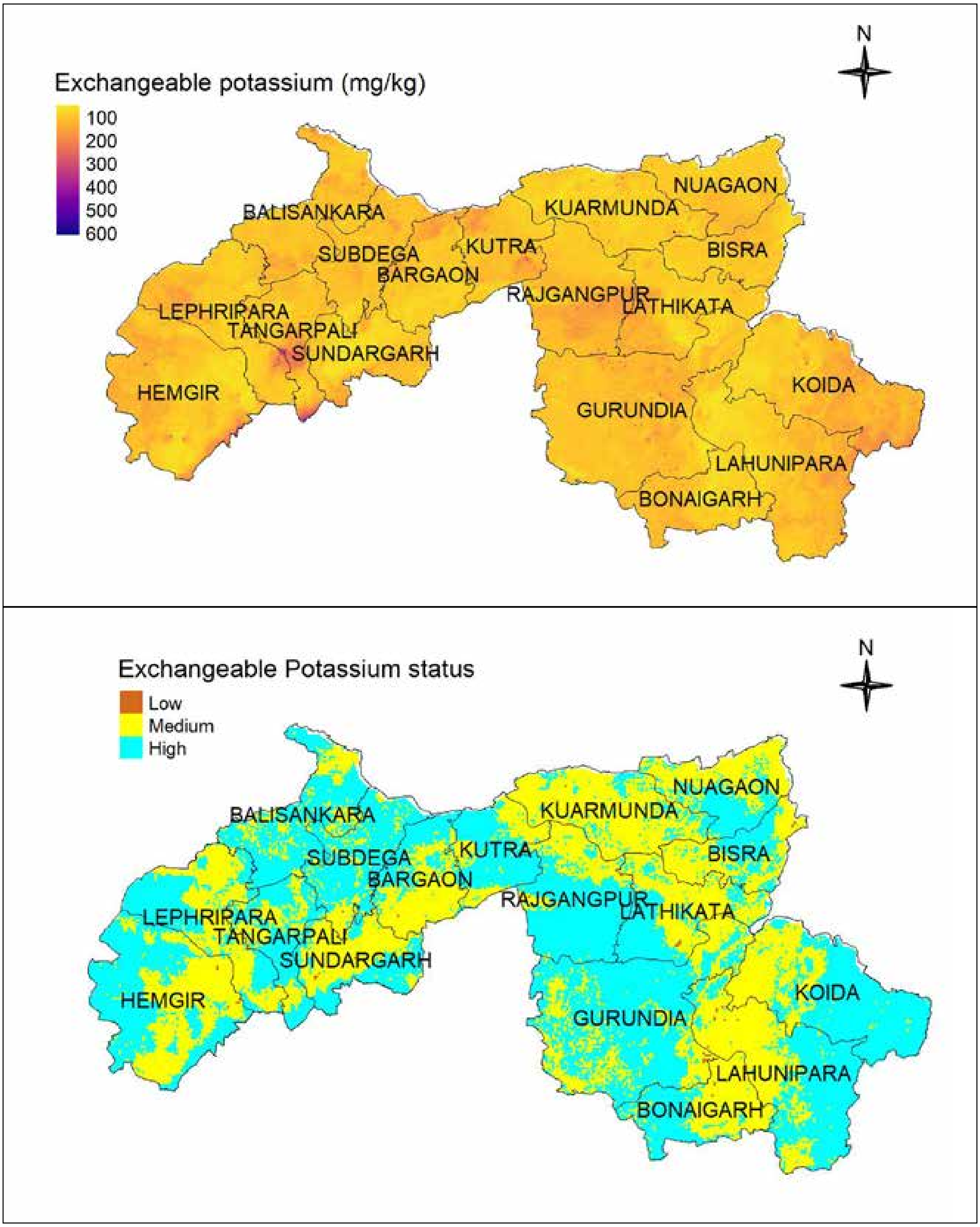


Figure 5.262. Status of exchangeable potassium in soils of Sundargarh district.

Available Sulfur

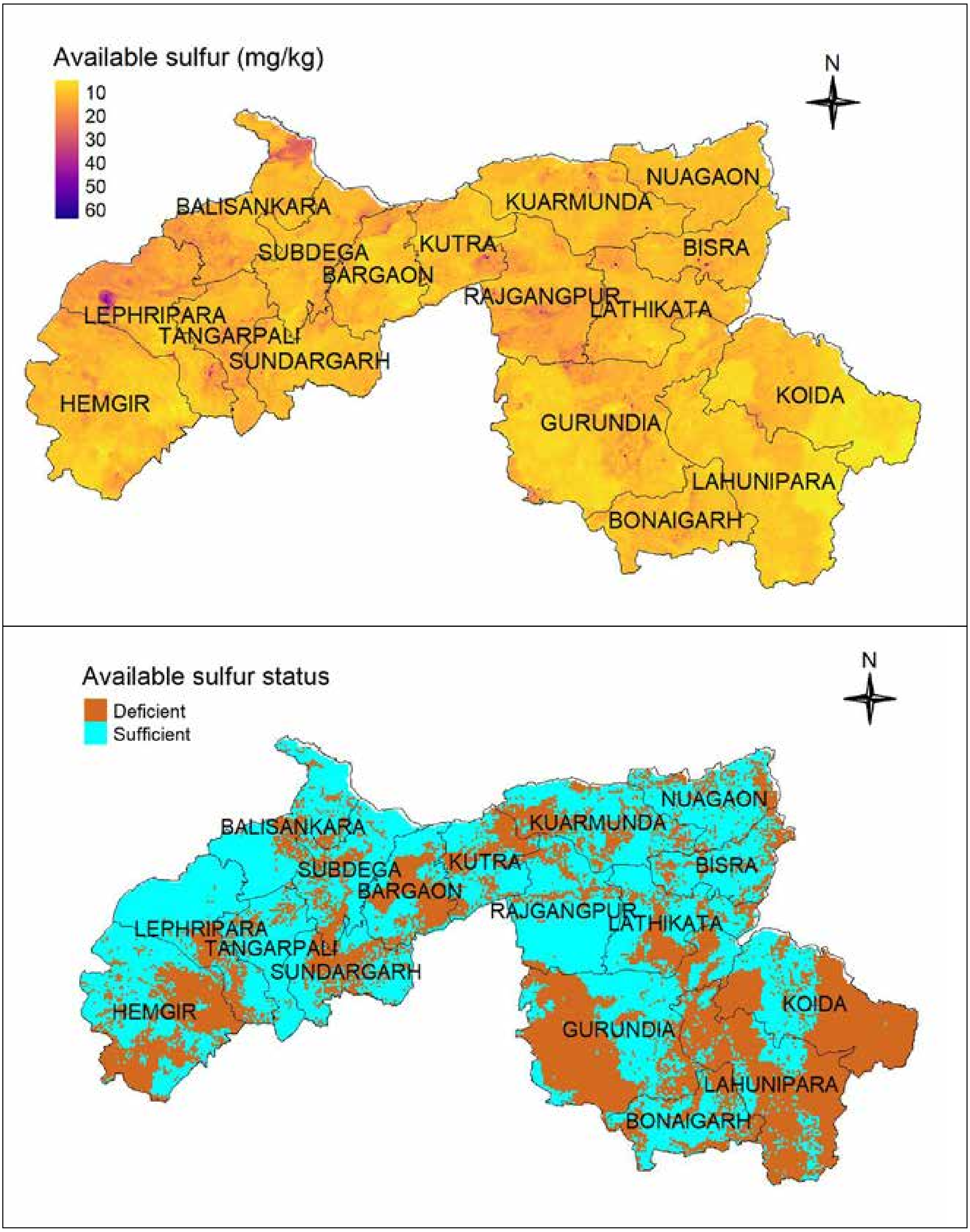


Figure 5.263. Status of available sulfur in soils of Sundargarh district.

Available Boron

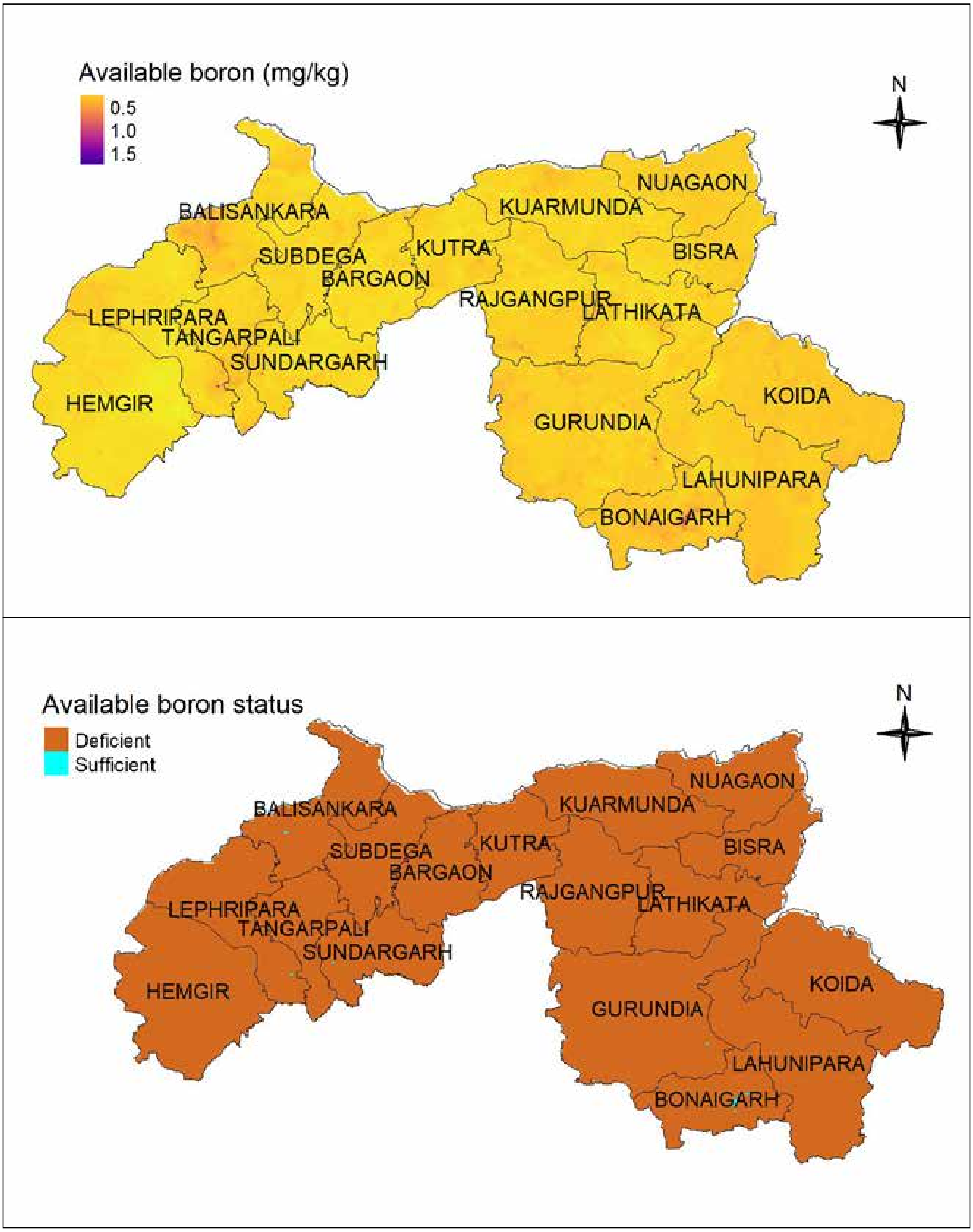


Figure 5.264. Status of available boron in soils of Sundargarh district.

Available Zinc

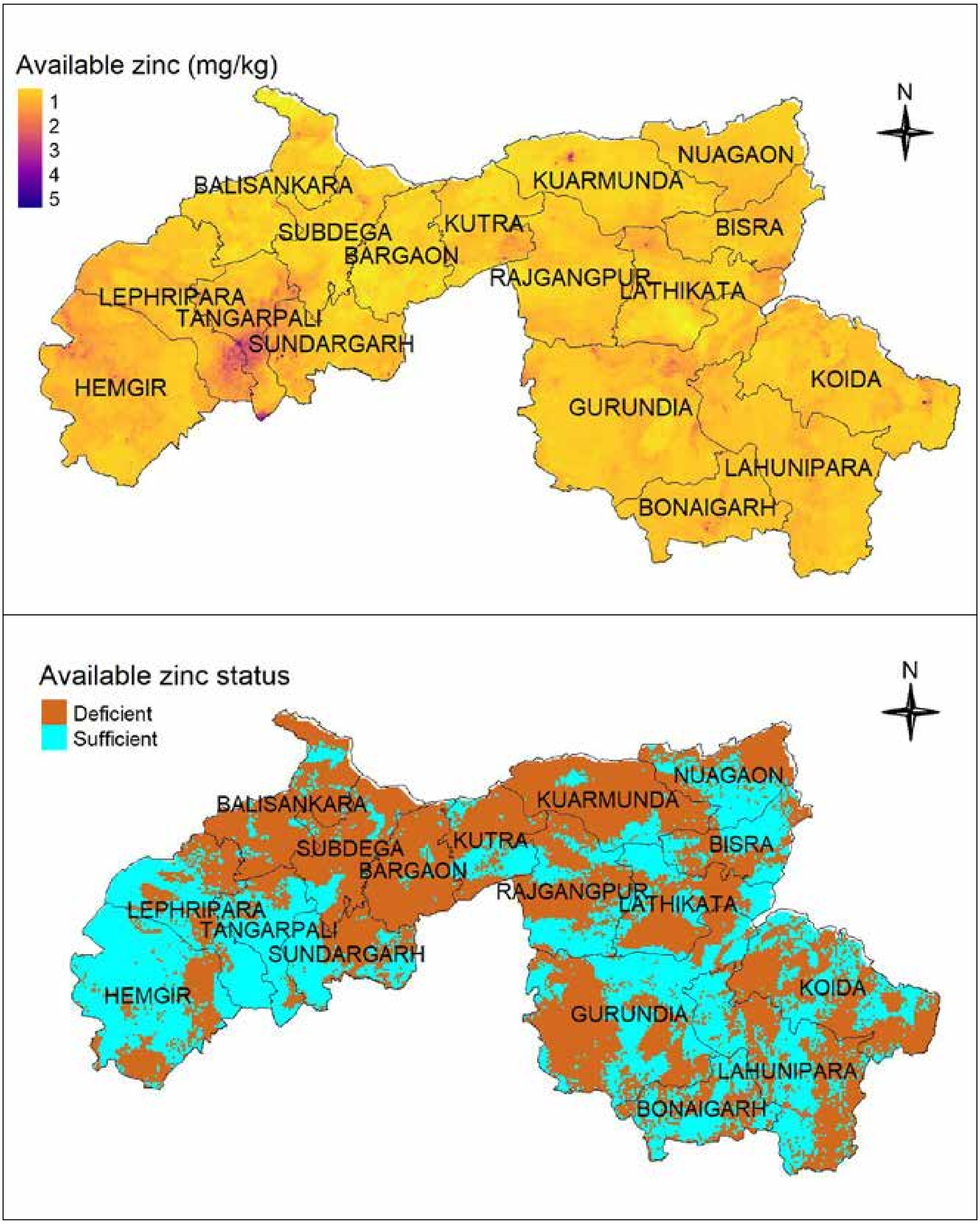


Figure 5.265. Status of available zinc in soils of Sundargarh district.

Chapter 6

Online Application for Soil test-based Fertilizer Recommendation

Mukund Patil and Gilbert Rozarios

Background

The creation of soil nutrient maps has been a critical output of the Bhoochetana project in Odisha. Data from the analysis of 40,265 soil samples collected across 30 districts was used as a database to develop soil fertility indices. The database was used to develop crop-wise fertilizer recommendations down to the village level and issue soil health cards to farmers. Since the printed soil health cards have limited reach and also involve huge cost and effort, a web-based application was envisaged to provide soil fertility information at village, block, or district levels in a seamless and cost effective manner. The data sets from the project were used to develop the web application.

Application Development

Developing the platform

The application was developed using a combination of PHP, an open-source server-side scripting language that can be embedded into an HTML document and MYSQL, an open-source data management system. During development stage, open-source software WAMP (version 2.2) was used as a testing environment on a local computer. WAMP is a bundle of softwares including apache web server (version 2.2.21), PHP processor (version 5.3.8), and MYSQL server (version 5.5.16). The existing web application is hosted on an ICRISAT server.

Database

The database includes information on locations, soil analysis results and crop-wise fertilizer recommendation. The location information is provided in three tables, for districts, blocks and villages (Fig. 6.1). The farmer-wise soil analysis data is stored in a table named ‘Farmer_soil_data’ which includes information on the farmers, values of soil fertility attributes and soil fertility status. Crop-wise fertilizer recommendations prepared in consultation with the state agriculture university are in the table named ‘crop_fert_rec_odisha’. Details of the database are given below:

Location

District

- id : Unique id of the district as per census records
- district_name: Name of the district as per census records
- state_id: Unique code of state as per census records

Block

- id: Unique id of the block as per census records
- district_id: Unique id of the district related to the block
- block_name: Name of the block as per census records

Village

- id: Unique id of the village as per census records
- block_id: Unique id of the block related to the village
- village_name: Name of the village as per census records

Soil analysis data

Farmer_soil_data

- id: Unique database id for soil sample
- shc_ref_no: Soil Health Card Number (ICRISAT data reference)
- farmer_ref_no: Unique farmer number (ICRISAT data reference)
- district: Unique id related to the district table in the database
- block: Unique id related to the block table in the database
- village: Unique id related to the village table in the database
- farmer_name: Name of the farmer
- latitude: Latitude of soil sample collection site in degree decimal
- longitude: Longitude of soil sample collection site in degree decimal
- mobile_no: Mobile number of the farmer
- survey_no: Survey number of the field from where the soil sample was collected
- year: Year of soil sample collection
- ph: pH of the soil sample
- ec: Electrical conductivity value (dS/m)
- oc: Organic carbon content (%)
- p: Available phosphorous content (kg/ha)
- k: Exchangeable potassium content (kg/ha)
- s: Available sulfur content (kg/ha)
- zn: Available zinc content (kg/ha)
- b: Available boron content (kg/ha)
- oc_result: Fertility status of organic carbon – low, medium or high (estimated)
- p_result: Fertility status of phosphorous – low, medium or high (estimated)
- k_result: Fertility status of potassium – low, medium or high (estimated)
- s_result: Fertility status of sulfur – deficient or sufficient (estimated)
- zn_result: Fertility status of zinc – deficient or sufficient (estimated)
- b_result: Fertility status of boron – deficient or sufficient (estimated)
- ph_result: Fertility status of pH – acidic, neutral or alkaline (estimated)
- ec_result: Fertility status of electrical conductivity – normal or injurious to crop (estimated)

Recommended dose of nutrients – Crop-wise

crop_fert_rec_odisha

- id: Unique id
- crop_id: Crop id related to the crops table

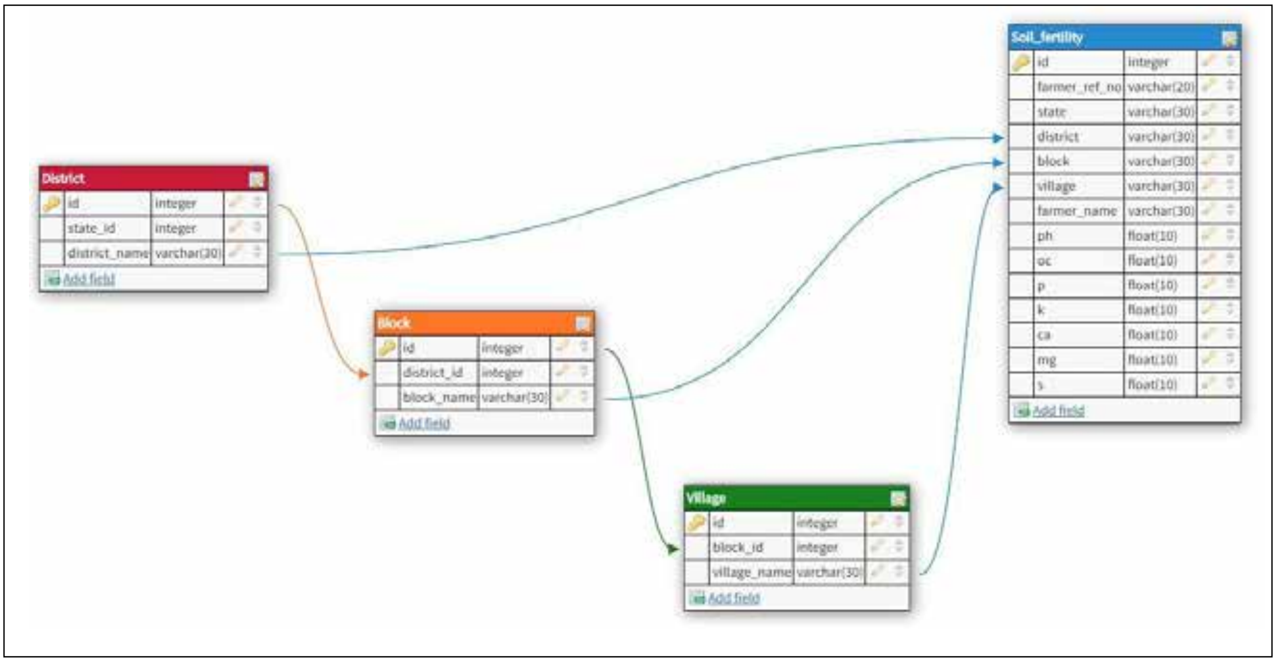


Figure 6.1. Relationship between location data and soil fertility dataset.

- n: Recommended dose for nitrogen
- p_2o_5: Recommended dose for phosphate
- k_2o: Recommended dose for potassium
- s: Recommended dose for sulfur
- zn: Recommended dose for zinc
- b: Recommended dose for boron

crops

- id: Unique id of the crop
- crops_name: Crop name

Process to obtain soil test-based crop-wise fertilizer recommendation

The decision rules to decide the status of macro and micronutrients in the soil are given in Tables 6.1 and 6.2. Three classes (low, medium and high) were used for macronutrients and two classes (deficient and sufficient) for micronutrients to decide fertilizer recommendations. For example, if the soil OC status is low, then the requirement for nitrogenous fertilizer will be 25% more than the recommended fertilizer dose (Table 6.3). In the case of micronutrients, the deficiency and sufficiency statuses were determined based on the critical limit set for the concentration of these elements in the soil. If the soil is deficient in micro- and secondary nutrients, i.e. the nutrient concentration is less than the critical level, then the full recommended dose of nutrients is suggested. To arrive at fertilizer doses at village/block/district levels, soil analyses results from village/block/district were aggregated to derive the nutrient indices relating to the three classes of macronutrients (OC, P and K) and percentage of samples deficient/sufficient in micro- and secondary nutrients (S, B, and Zn). Aggregated values were used to decide the nutrient dose (Table 6.3). The process followed to calculate fertilizer recommendations is shown in Table 6.6 and Figure 6.2.

Table 6.1. Soil fertility classes based on macronutrients' (kg/ha) content.

Nutrient	Low	Medium	High
Organic carbon (%)	<0.5	0.5-0.75	>0.75
Available P (mg/kg)	<5	5-10	>10
Available K (mg/kg)	<50	50-100	>100

Table 6.2. Critical limits of micronutrients (mg/kg) in soil.

Nutrient	Critical level
Available S (mg/kg)	10
Available Zn (mg/kg)	0.75
Available B (mg/kg)	0.58

Table 6.3. Soil fertility criteria for recommended fertilizer doses based on percentage of deficient samples at the village, block and district levels.

Nutrient	Nutrient index or deficiency levels (DL)	Recommended dose
N, P,K	Low	25% more than the recommended dose of nutrient
N, P, K	Medium	Recommended dose of nutrient
N, P, K	High	Recommended dose of nutrient
S, Zn, B	<=10%	No application of nutrient
S, Zn, B	10-25%	25% of the recommended dose of nutrient
S, Zn, B	25-50%	50% of the recommended dose of nutrient
S, Zn, B	>50%	100% of the recommended dose of nutrient

Table 6.4. Nutrient content in solid fertilizers (% by weight).

Fertilizer	Total N	P_2O_5	K_2O
Urea	46		
Potassium chloride (powder/granular)			60
Ammonium Phosphate	18	46	

Table 6.5. Nutrient content in solid fertilizer (micronutrient).

Fertilizers	Element	Content (%)
Zinc Sulphate*	Zn	21.00
Borax	B	10.50
Agribor	B	20.00
Gypsum	S	23.00

Table 6.6. Process to obtain soil test-based crop-wise fertilizer recommendations.

Step no	Process
1	**Input** – Select state from the list
2	**Process** – Based on the state selected, a list of districts appears in the District dropdown box
3	**Input** – Select the district from the list
4	**Process** – Based on the district selected, a list of blocks appears in the Block dropdown box
5	**Input** – Select the block from the list **OR** go to Step 9 to get the district level recommendations
6	**Process** – Based on the block selected, a list of villages appears in the Village dropdown box
7	**Input** – Select the village from the list **OR** go to Step 9 to get the block level recommendations
8	**Input** – Select the crop from the available list
9	**Input** – Click on submit
10	**Process** – Based on the level selected (village/block/district), values of the fertility parameter will be aggregated to estimate average, minimum and maximum values of fertility parameter, nutrient indices and deficiency levels.
11	**Process** – *Deciding the multiplication factor (n) for macronutrients based on nutrient indices* If the nutrient index is low, then n = 1.25 If the nutrient index is medium, then n = 1 If the nutrient index is high, then n = 0.75 *Deciding the multiplication factor (n) for micro and secondary nutrients based on deficiency levels* If deficiency level is less than 10, then n = 0 If deficiency level is between 10 and 25, then n = 0.25 If deficiency level is between 25 and 50, then n = 0.5 If deficiency level is greater than 50, then n = 1
12	**Process** - Search nutrient recommendations from the database for the crop selected in Step 8
13	**Process** – Adjust the recommended nutrient dose using the multiplication factors derived in Step 11 to obtain soil test-based nutrient recommendations for selected crops
14	**Process** – Estimate fertilizer quantity based on the nutrient content in the fertilizer as mentioned in Tables 6.4 and 6.5
15	**Output** – Display results in tabular form (Figures 6.3 – 6.5)

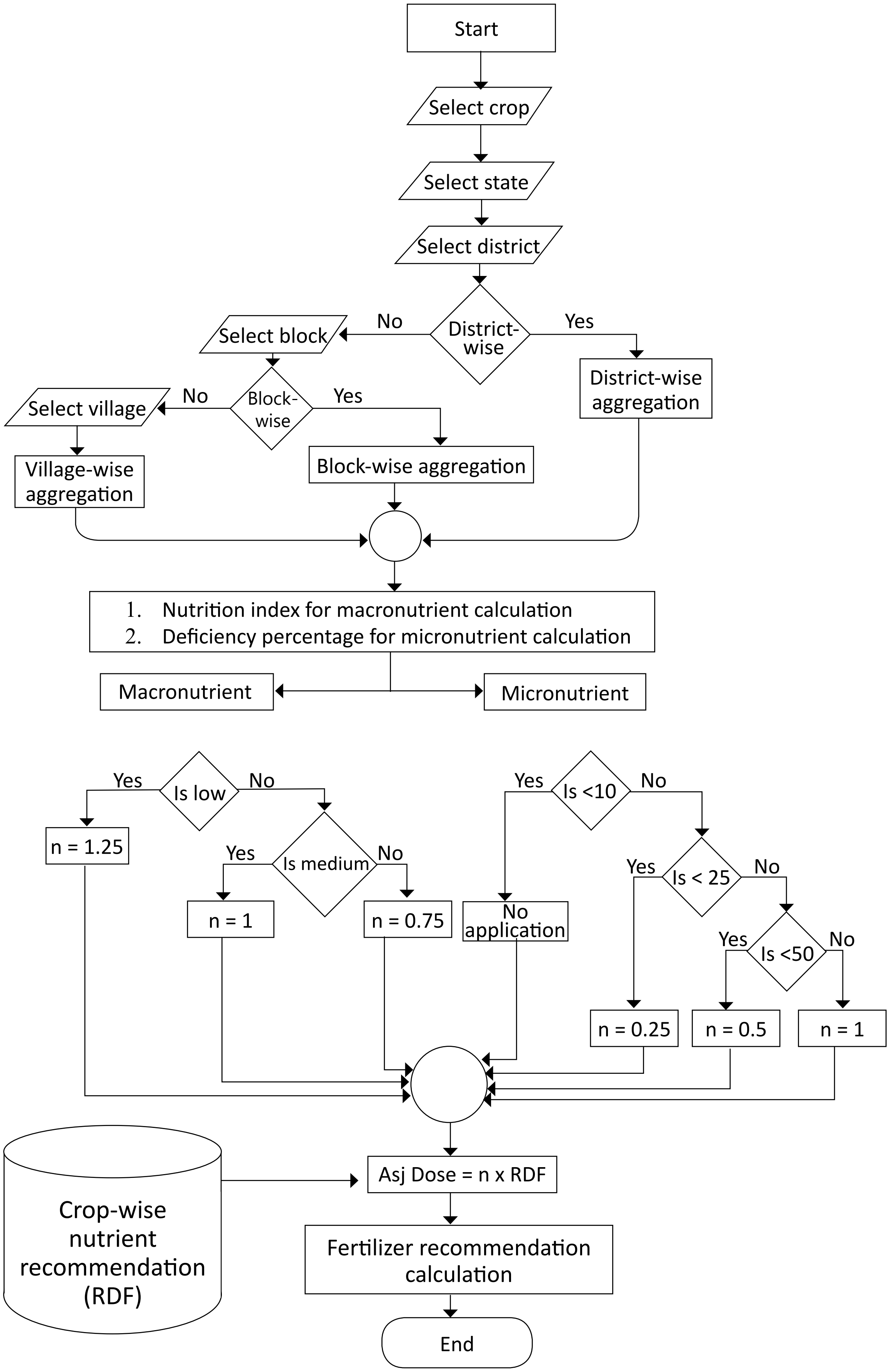


Figure 6.2. Flow diagram depicting the calculation of crop-wise fertilizer recommendation.

How to use the WebApp

The application is hosted on the ICRISAT server and can be accessed at http://111.93.2.168/kgs/fertilizer_rec.php. The web page provides users the option to view the soil fertility status at the village, block and district levels. A step-by-step process to access the information is given in Table 6.7 and depicted in the application interface in Figures 6.3 to 6.5.

Table 6.7. Process to access information on soil fertility status and crop-wise fertilizer recommendations in the application.

Step No.	User action	Web page response
Information at village level		
1	Select State	List of districts appears below the state list
2	Select the district from the district list	List of blocks appears below the district list
3	Select the block from the block list	List of villages appears below the block list
4	Select the village from village list	Village selected in the list
5	Select the crop from the crop list	Crop selected in the list
6	Click the Submit button to get the soil fertility status at the village level and fertilizer recommendation	Displays soil fertility table with fertilizer recommendation
Information at block level		
7	Follow Steps 1, 2 and 3, and then go to Step 5	
8	Select the block from the block list	Village list appears below the block list
9	Click the Submit button to get the soil fertility status at the block level and fertilizer recommendation	Displays the soil fertility table with fertilizer recommendations
Information at district level		
10	Follow Steps 1 and 2, and then go to Step 5	
11	Select the district from the district list	Block list appears below the district list
12	Click the Submit button for a display of the soil fertility status at the district level and fertilizer recommendation	Displays the soil fertility table with fertilizer recommendations

Fertilizer Recommendation

State

Odisha

District

ANGUL

Block

ANUGUL

Village

BALIJERENGA

Crop Name

Sorghum

Area (ha) required for farmer level

1

SUBMIT

Fertilizer Recommendation for Sorghum
Village name: BALIJERENGA

Parameter	Fertility Status	Range	Recomendation (kg/ha)
ph		6.36 - 7.91	
ec		0.06 - 0.22	
p	medium	4 - 38.62	DAP :65
oc	medium	0.49 - 1.41	Urea: 105
k	High	184.85 - 453.4	
zn	dl (70%)	0.22 - 1.68	ZNSO4 (20% Zn):25
s	dl (50%)	5.42 - 31.63	Gypsum (15% S):83
b	dl (50%)	0.34 - 0.74	B fertilizer(20% B):1

dl: Deficiency

Figure 6.3. A page from the application interface showing village-level soil fertility status and crop-wise fertilizer recommendation.

Fertilizer Recommendation

State

Odisha ▾

District

ANGUL ▾

Block

ANUGUL ▾

Village

Select Village ▾

Crop Name

Sorghum ▾

Area (ha) required for farmer level

1

SUBMIT

Fertilizer Recommendation for Sorghum
Taluk name: ANUGUL

Parameter	Fertility Status	Range	Recomendation (kg/ha)
ph		4.54 - 8.39	
ec		0.02 - 0.9	
p	medium	1.39 - 83.59	DAP :65
oc	medium	0.1 - 1.42	Urea: 105
k	medium	40.55 - 866.6	MOP :50
zn	dl (62%)	0.04 - 2.68	ZNSO4 (20% Zn):25
s	dl (46%)	0.12 - 224.41	Gypsum (15% S):83
b	dl (76%)	0.02 - 1.11	B fertilizer(20% B):3

dl: Deficiency

Figure 6.4. A page from the application interface showing block-level soil fertility status and crop-wise fertilizer recommendation.

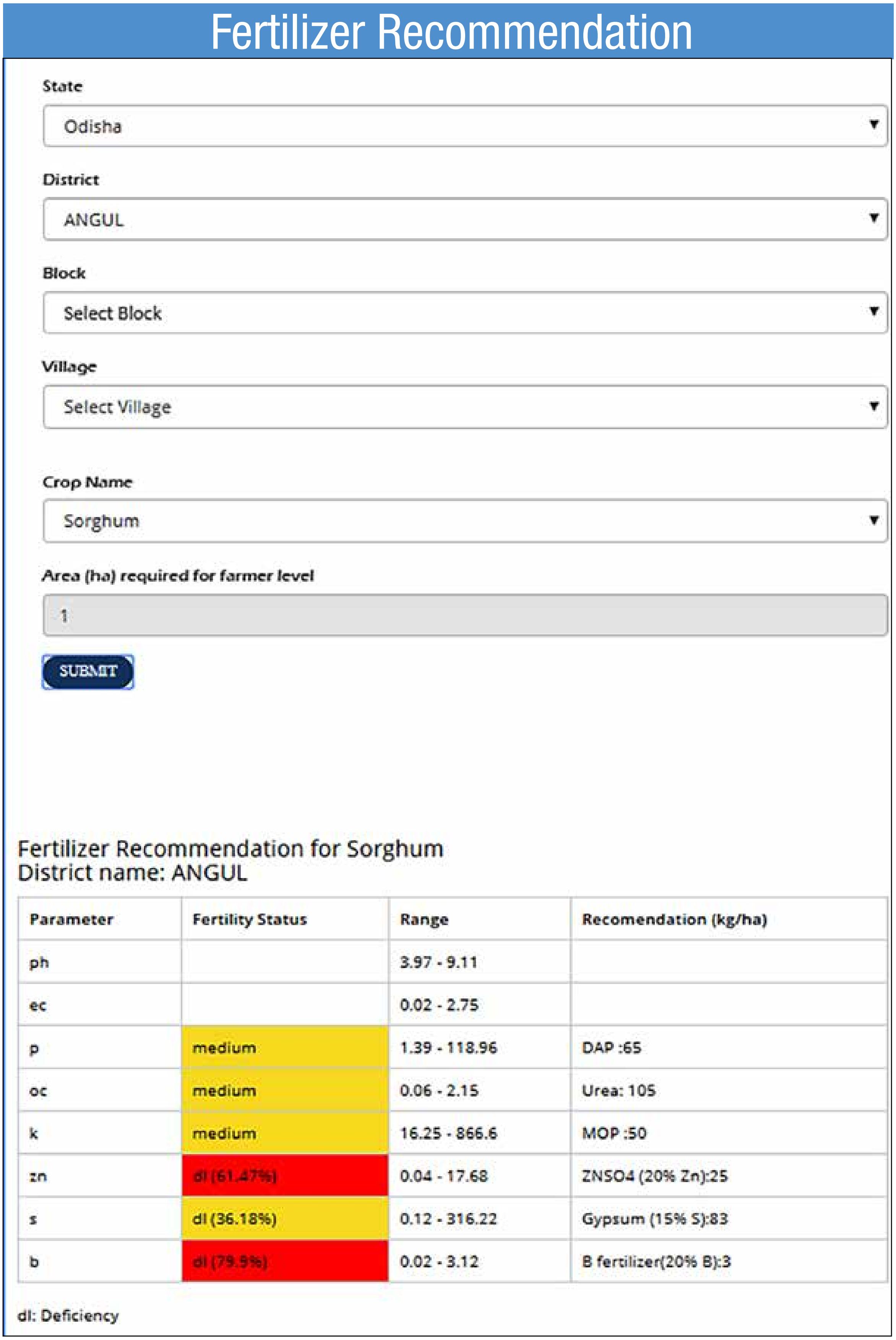


Figure 6.5. A page from the application interface on district-level soil fertility status and crop-wise fertilizer recommendation.

Notes

ICRISAT Locations

About ICRISAT

ICRISAT
INTERNATIONAL CROPS RESEARCH INSTITUTE FOR THE SEMI-ARID TROPICS
CGIAR

ICRISAT works in agricultural research for development across the drylands of Africa and Asia, making farming profitable for smallholder farmers while reducing malnutrition and environmental degradation. We work across the entire value chain from developing new varieties to agribusiness and linking farmers to markets.

ICRISAT appreciates the supports of funders and CGIAR investors to help overcome poverty, malnutrition and environmental degradation in the harshest dryland regions of the world. See www.icrisat.org/icrisat-donors.htm

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