Food and Agriculture Organization
of the United Nations

AGRO-ECOLOGICAL *Atlas*

of the Republic of North Macedonia

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AEZ	Agro-ecological zone
CAP	Common agricultural policy
DEM	Digital elevation model
E_o	Evaporation from the open water surface
ET	Evapotranspiration
ET_o	Reference crop evapotranspiration
EU	European Union
EU-CAP	European Union Common Agricultural Policy
FAO	Food and Agriculture Organization of the United Nations
GDP	Gross domestic product
GIS	Geographic information system
HMS	Hydrometeorologica service
IPARD	Instrument for pre-accession assistance for rural development
LCCS	Land cover classification system
LGP	Length of growing period
LPIS	Land parcel identification system
M	Meter(s)
MASIS	Macedonian soil information system
MAFWE	Ministry of Agriculture, Forestry and Water Economy
MKD	Macedonian denar
NAEZ	National agro-ecological zones
P-NAEZ	Partecipatory national agro-ecological zones
RS	Remote sensing
SRTM	Shuttle radar topographic mission
UN	United Nations
USDA	United States Department of Agriculture

Abbreviations and acronyms


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Agriculture has an important role in North Macedonia and in 2017 it accounted for 7.9 percent of the gross domestic product (GDP) in the country. However, agriculture's share of the country's GDP has been decreasing for the past decade, and in 2010 the share of the national production GDP of agriculture was 10.1 percent.

Therefore, the need to improve agricultural productivity has become an important challenge for the country. In the past two decades, there has been an improvement in the yield of major crops, but it remains lower than the European Union (EU) averages, particularly in the case of cereals. Additionally, with climate variability the country has experienced severe damages to production from early frosts, drought and floods. And for a country where 42 percent of the population lives in rural areas and can be considered as a predominantly agricultural country, it is still a net importer of both raw and processed foods including agricultural products.

North Macedonia invests a significant portion of the national budget to supporting agriculture, with 42.6 million US dollars allocated in 2018 for direct payments in agriculture alone. Which makes it necessary to develop tools that can support policy design, and implementation in agriculture. Furthermore, is an EU candidate country in the process of pre-accession to the EU. As such, it tailors many of its national policy reform to the forms and practices of the EU, including in the agricultural sector. With the upcoming reform in the European Union Common Agricultural Policy (EU–CAP) starting from 2020 from a prescriptive to a results-based framework, the country needs a significant strengthening of its agro-ecological information systems. More specifically, future support measures under the EU–CAP will be based on nationally defined targets, as contributions to overall EU objectives. For which measurable economic and environmental indicators will be a necessity for every member country, and the same would apply for the North Macedonia, should it continue to approximate legislation and policy in the making of EU. Namely, in the case of the instrument for pre-accession assistance for rural development (IPARD) funds that country accesses from the EU, which emulate a segment of the CAP and making their agricultural sector and rural areas more sustainable.

To address all the above, advanced information and analytical products such as the Food and Agriculture Organization of the United Nations (FAO)'s agro-ecological zoning are being developed. In the case of North Macedonia, the delineation of agro-ecological zones (AEZ) specific to crops presents a useful preliminary evaluation of the country's agricultural potential and provides a tool for regional and environmentally sustainable development planning.

Agro-ecological zoning refers to the division of an area of land into land resource mapping units, having a unique combination of landform, soil and climatic characteristics, and/or land cover having a specific range of potentials and constraints for agricultural land use. Through the adoption of agro-ecological zones efficiency and sustainable development planning is made more accessible to decision-makers and stakeholders in agriculture, by allowing for the planning of cropping systems and crops in a specified region based on critical analysis and assessment of agro-climatic and agro-edaphic constraints as available resources for crop production.

In 2012, in North Macedonia the first step to the development of such digital tools and systems was taken, and in 2015 with the technical and financial support of FAO, the Ministry of Agriculture, Forestry and Water Economy (MAFWE), along with the Agriculture Institute and the Faculty of Agricultural Sciences and Food of the University of St. Cyril and Metodi, developed the Macedonian soil information system (MASIS). That represents a comprehensive system with digital spatial information on soils in the country.

Executive summary

However, considering climate change and other environmental factors and resources further steps were taken to develop AEZ in the country. For this purpose, MAFWE with the support of FAO's Technical Cooperation Program project TCP/MCD/3602 (Assessment of agriculture production through NAEZ and LRIMS and scenario development in the Republic of North Macedonia) initiated activities to adapt FAO's AEZ methodology to local needs through a collaborative process, which led to the development of participatory national agro-ecological zones (NAEZ) in the country. The effort was undertaken by forming a wide technical working group with representatives from academia, the Hydro Meteorological Service, State Statistics Office, and the Ministry of Environment and Spatial Planning. Which led to the creation of a broad agro-environmental database.

With AEZ, policy-makers can use information on land characteristics such as soil quality, topography, climate, water availability, agricultural land use, yield, and profitability to formulate optimal policies for sustainable agricultural production. Land characteristics can further be evaluated for their production potential, which leads making final recommendations regarding "what" should be grown, and "where" and "how" it should be grown.

The entire AEZ can be found on www.agroekologija.mk, along with a comprehensive spatial digital database, of the varied agro-ecological layers developed in the scope of the project open for public access. On the website, which is entitled the Macedonian agri-environmental information system, also made available are training materials for the use of the geographic information system (GIS), including training videos and guides.

Introduction

Agro-ecological zones in the Republic of North Macedonia

There are various methodologies for the agro-ecological zones (AEZ) depending on specific objectives and available data. Some approaches are focused on producing aggregated information supporting regional or national plans, others are more local and detailed solutions for specifically developed for specific purposes. Since there are different terrain and climate dynamics and the importance of the regions and countries, there is no globally accepted formula or solution. Therefore, working with the country technical experts and the use of local climate, soil, water, and socio-economic data is critical. And integrating national knowledge into the methodology to develop tailored national agro-ecological zones (NAEZ) for country-specific requirements and priorities is vital.

To achieve the best results participatory NAEZ (P-NAEZ) methodology is developed which is tailored in the case of the Republic of North Macedonia collaboration of AEZ experts of FAO and technical working group which brings together of the country experts and local knowledge. Establishing technical working group of the country is one of the most important requirements by involving all actors into the systematic as a participatory process not only to ensure sustainability and the regular updates of the project outputs, but also to build the capacity of national experts.

As presented in the general flow chart (Figure 1), all data and information about the agri-environmental resources, such as soils, water, land forms, climate, crops and socio-economic systems were organized and stored in integrated database called "land resource database", to be incorporated into systems that implement models, pattern recognition, and optimization algorithms. Gathering and centralizing all of available data, which usually countries have under different domains owned by different Institutional bodies, with some improvement and additions, is a very successful effort for consolidating the national environmental database and also achieving the aim of strengthening agro-climatic monitoring and analysis of agriculture production systems. Based on the information coming from the country experts, the variables and the case -specific methodology to be considered in the formulation of the NAEZ was decided and applied. Through this participatory AEZ approach, the methodology was applied to great success, to develop high-resolution agro-climatic zones, agro-ecological zones, crop yield projections, income projections and yield gaps in the country with a high 50 metres per pixel resolution.

Figure 1 Agro-ecological zones flow in North Macedonia

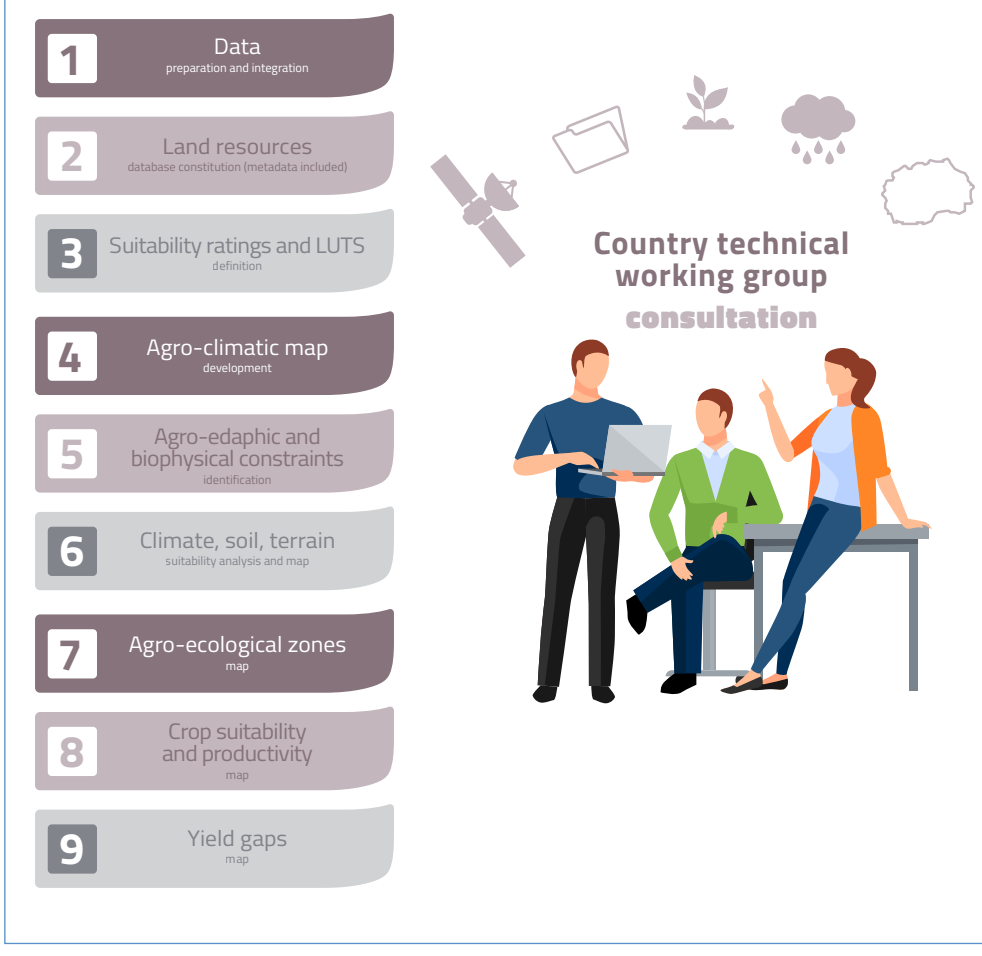
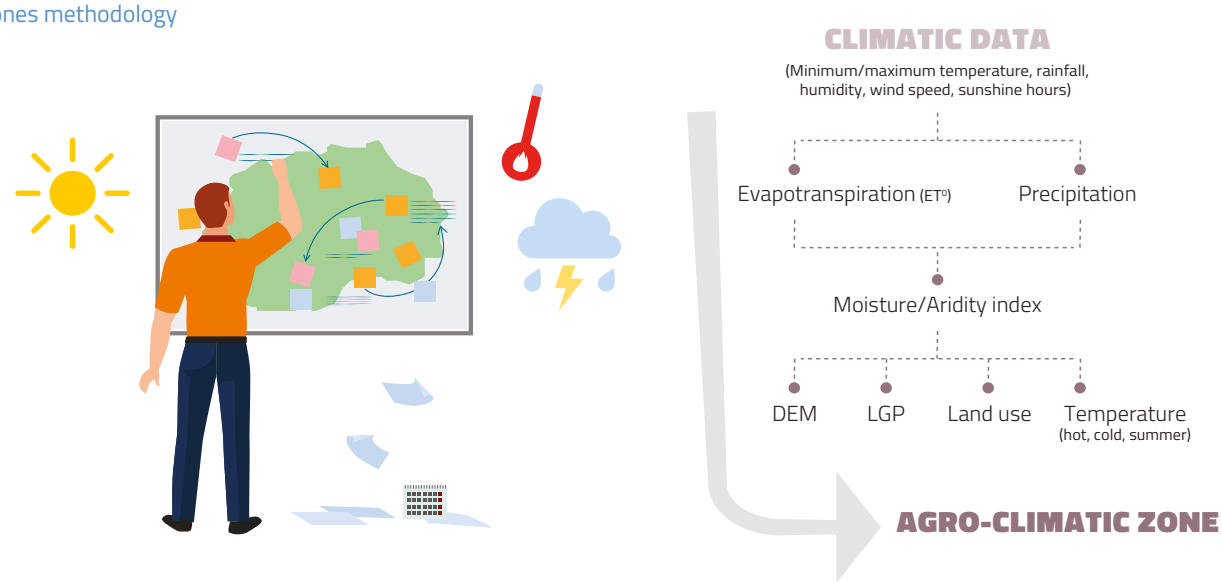
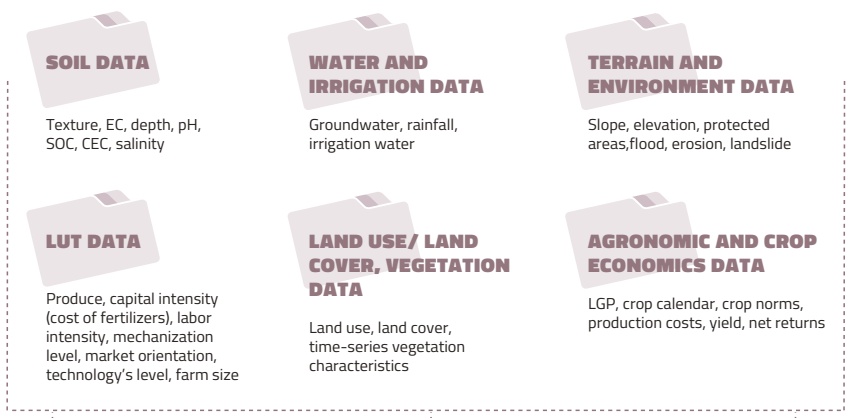
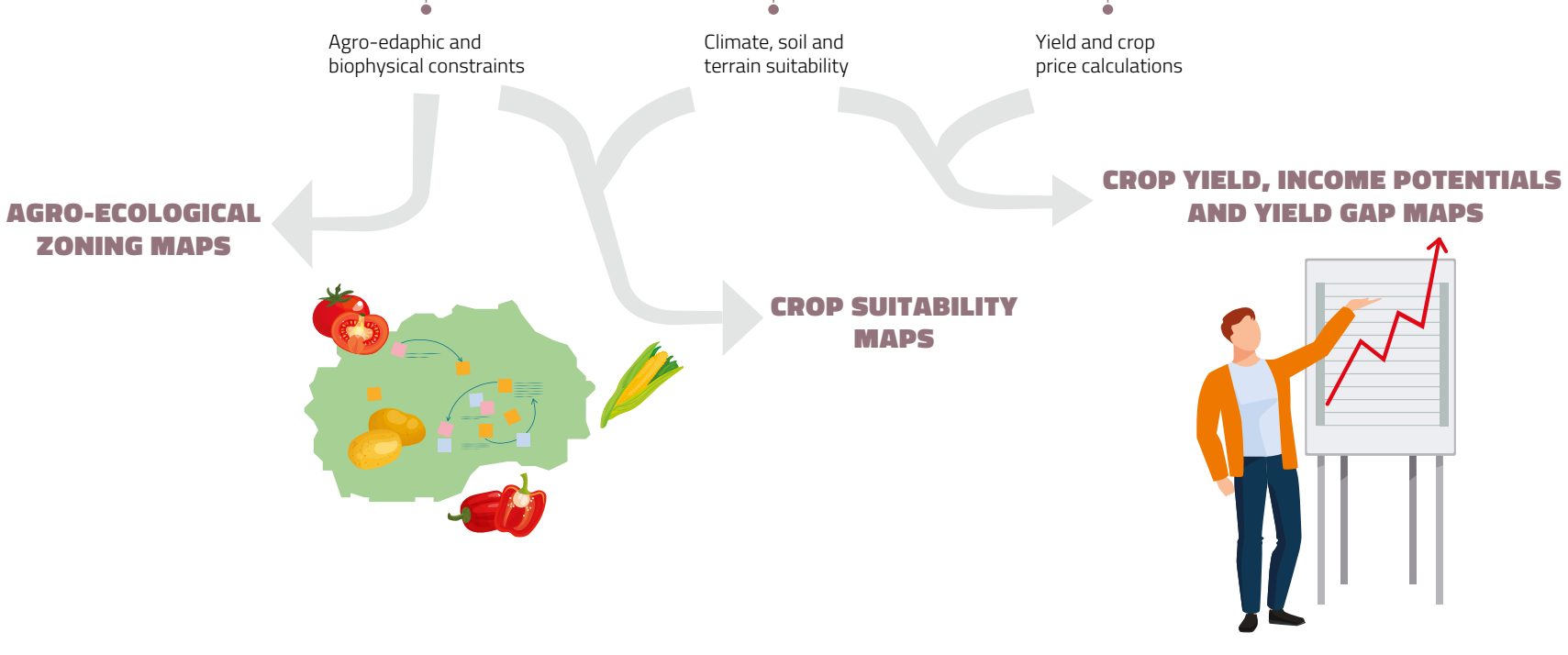


Figure 2 Agro-ecological zones methodology







1

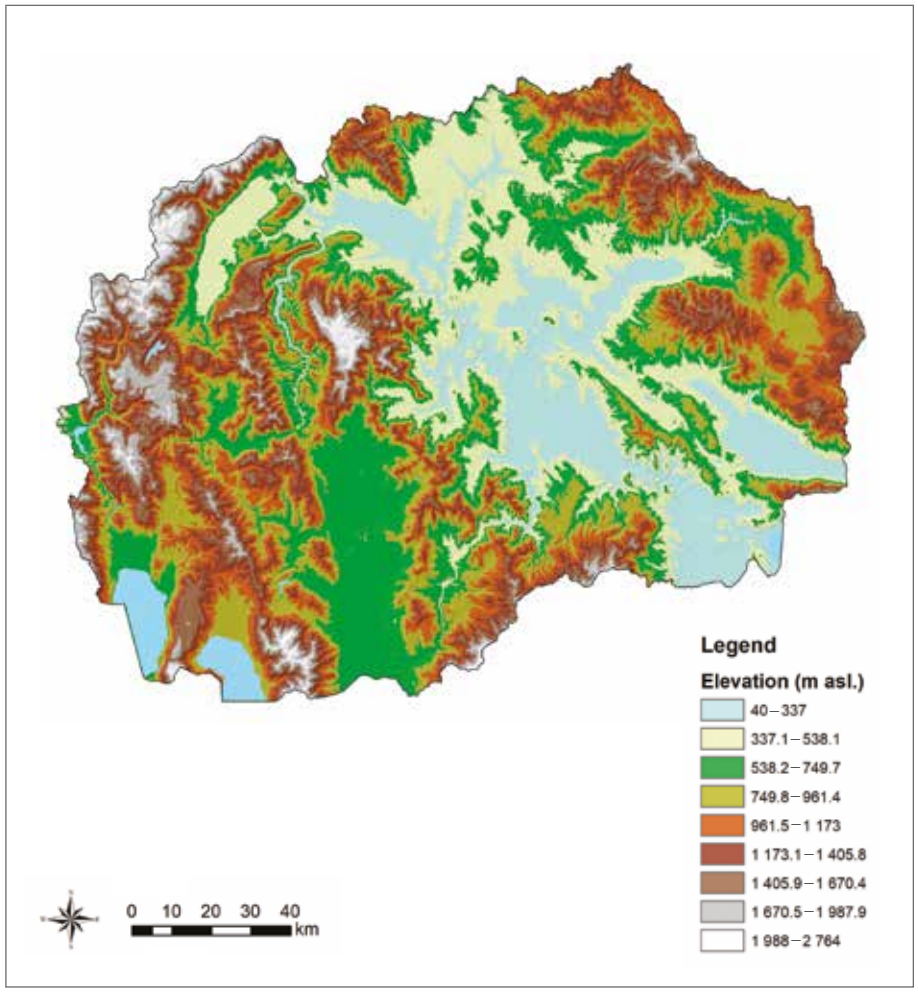
Agro-ecological zones dataset

1.1 Topography

To conduct agro-ecological zoning in the country the initial step was the collection of available country and global data. In the case of topography, the Republic of North Macedonia has highly accurate topographic data prepared by the Ministry of Agriculture, Forestry and Water Economy (MAFWE) as part of the country's land parcel identification system (LPIS). This system is part of the ministry, under which every five years a new orthophoto and digital elevation model (DEM) are developed. For the development of the agro-ecological zones, the ministry provided the latest DEM and orthophoto of the country with 0.3-meter spatial resolution, developed in 2018 based on aerial imagery taken in 2017. The DEM was produced from stereo pair aerial images with spatial resolution of 0.3 m from 2017. The spatial resolution of the DEM was 5 meters. This product was resampled to 20 meters because it was more practical to use a coarser scale to produce the output layers.

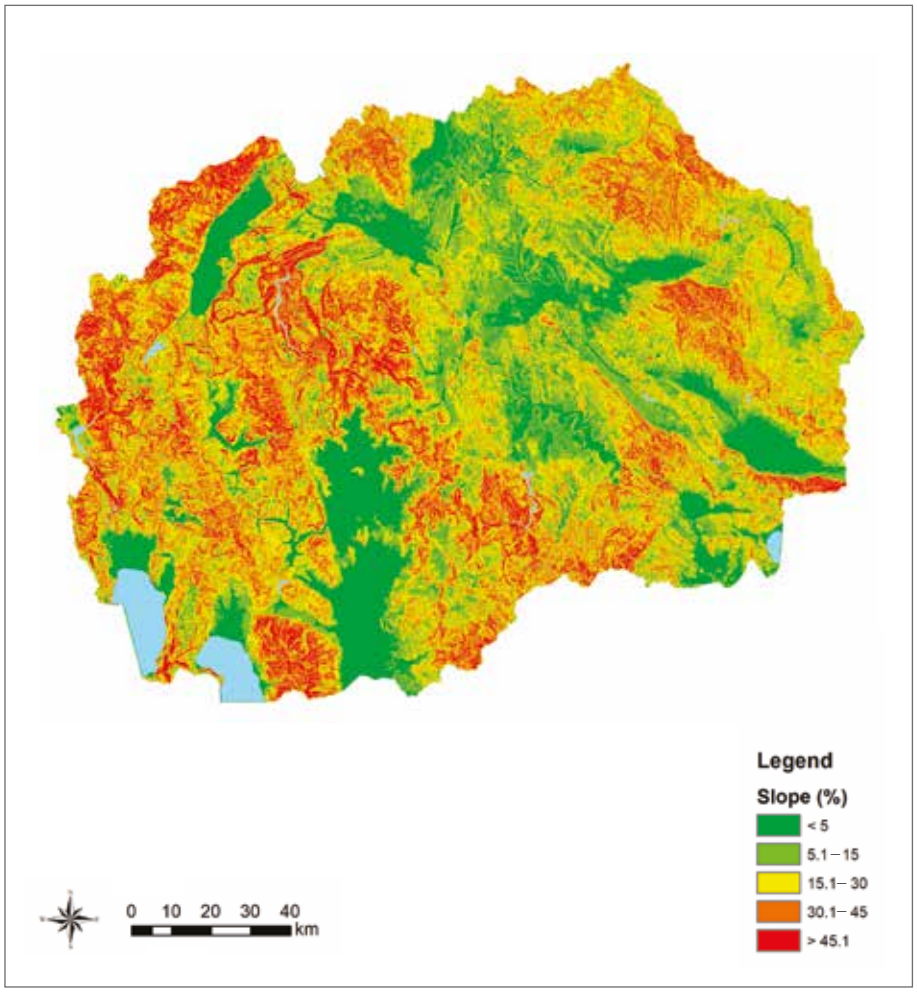
In the maps below are presented: the distribution of the country's elevation developed from the DEM (on the left), and the distribution of the slopes rescaled in 20-meter spatial resolution for easier processing (on the right).

ELEVATION in North Macedonia



Source: Ivan Mincev (FAO).
Map conforms to UN world map, February 2019.
Dashed lines on maps represent approximate border lines for which there may not yet be full agreement.

SLOPE in North Macedonia



Source: Ivan Mincev (FAO).
Map conforms to UN world map, February 2019.
Dashed lines on maps represent approximate border lines for which there may not yet be full agreement.

1.2 Soil data

Soil data in the country was obtained from the Macedonian soil information system (MASIS), which was developed with financial and technical support from FAO in 2015, as part of FAO's technical cooperation program. MASIS includes a variety of layers for the country's soils based on historical research and limited sampling in the field.

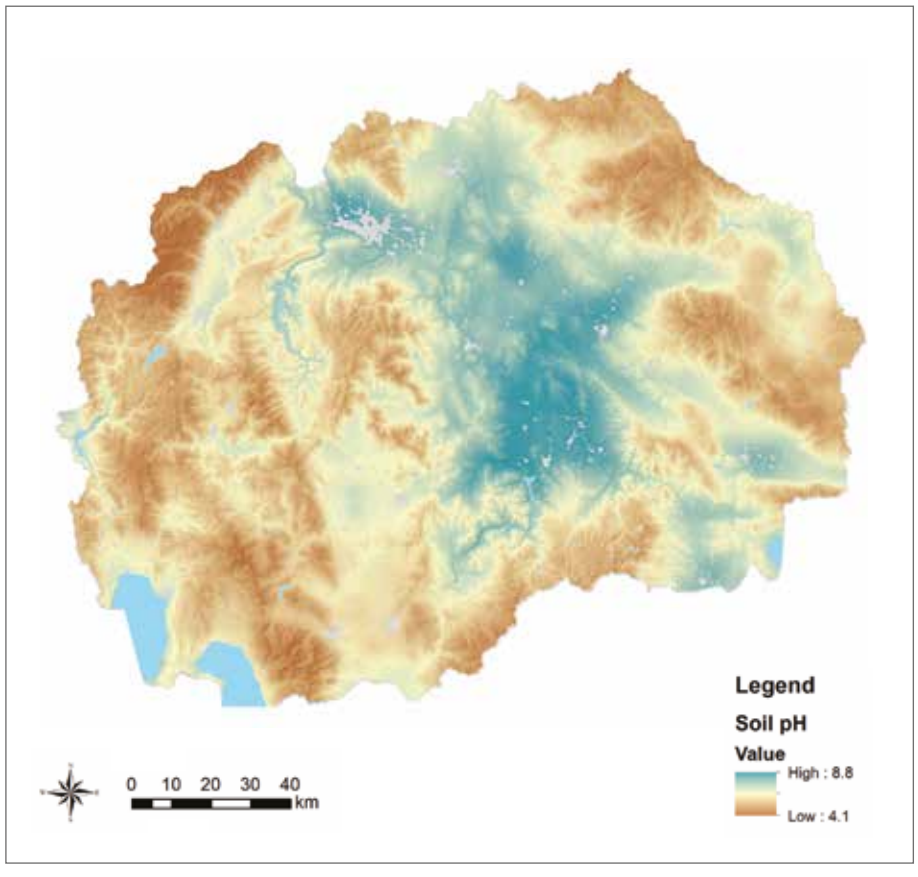
From the available data of the soil information system, the pH of the soil and the soil depth layers were utilized (maps below).

Additionally, soil texture layer was developed from the integration of clay, sand and silt content layers in fit with the United States Department of Agriculture (USDA) soil texture pyramid.

Figure 3 Macedonian soil information system web portal

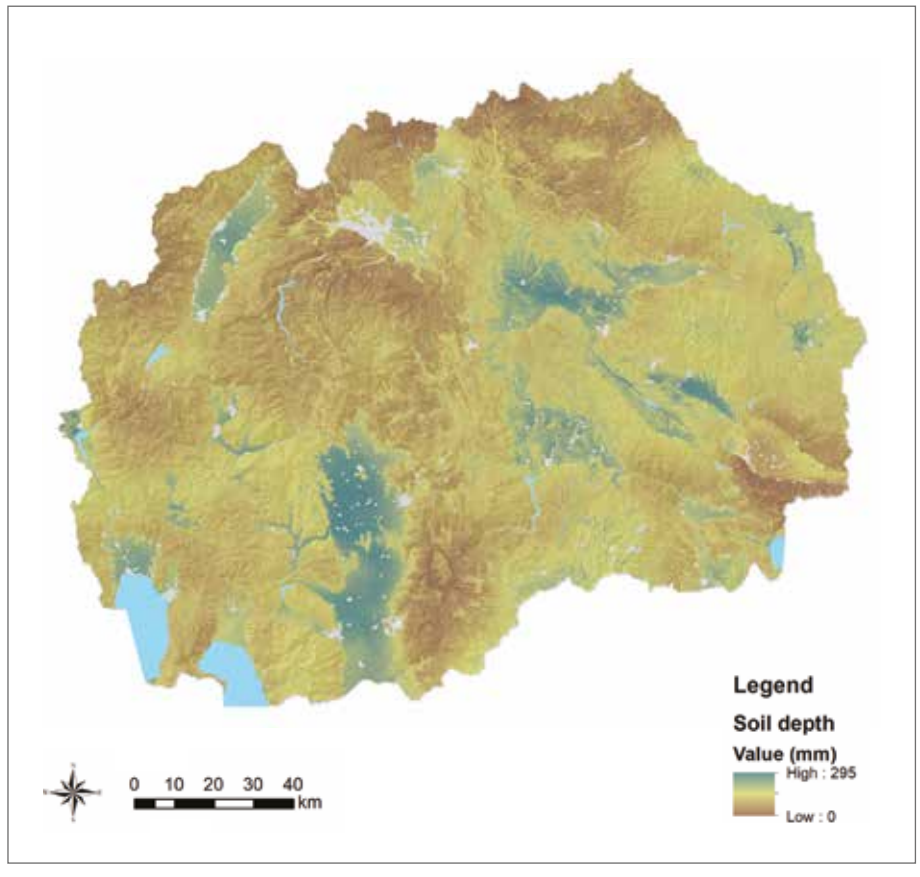
Source: www.maksoil.ukim.mk/masis/

SOIL pH in North Macedonia



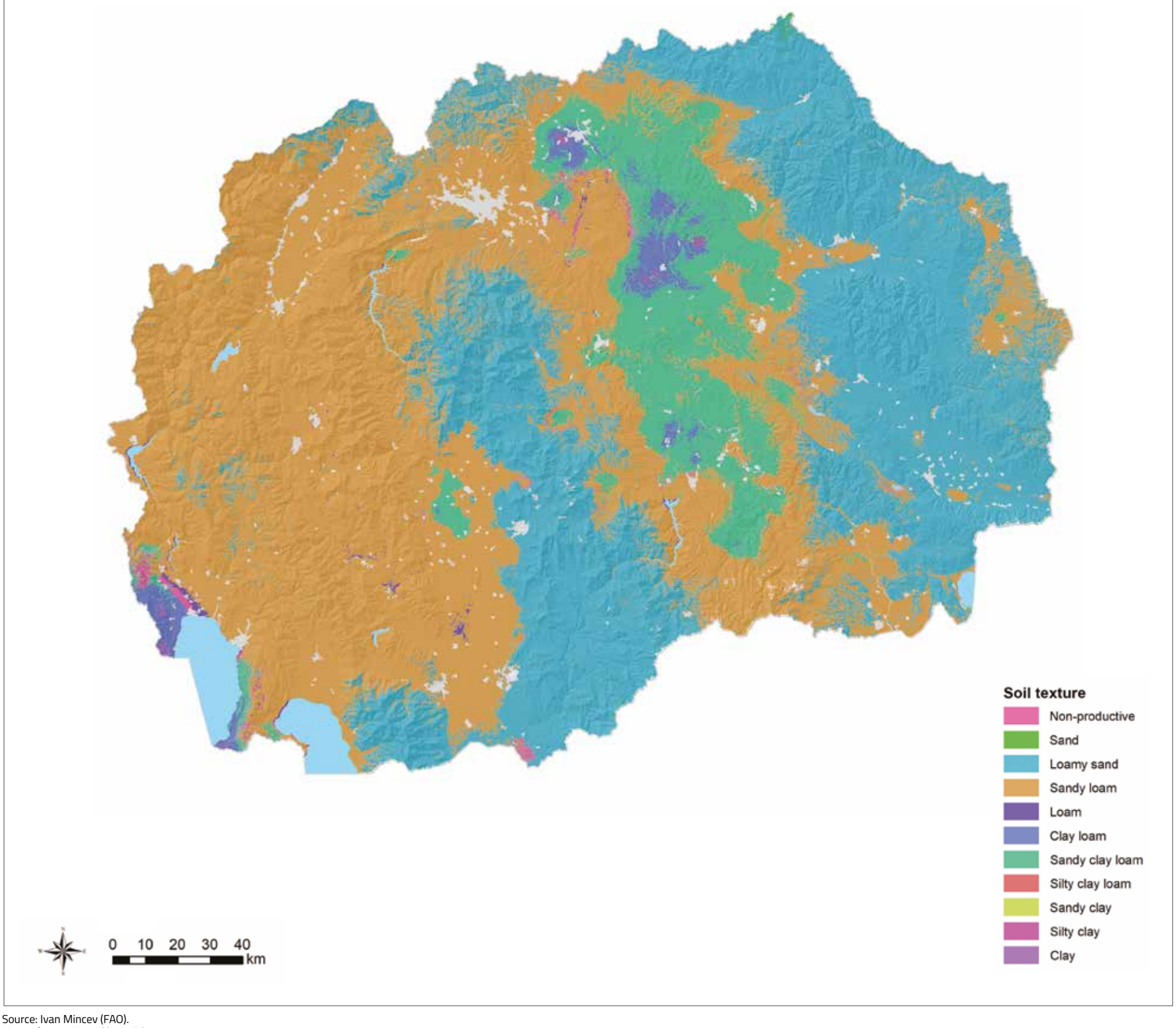
Source: Ivan Mincev (FAO).
Map conforms to UN world map, February 2019.
Dashed lines on maps represent approximate border lines for which there may not yet be full agreement.

SOIL DEPTH in North Macedonia



Source: Ivan Mincev (FAO).
Map conforms to UN world map, February 2019.
Dashed lines on maps represent approximate border lines for which there may not yet be full agreement.

Soil texture in North Macedonia



Source: Ivan Mincev (FAO).
Map conforms to UN world map, February 2019.
Dashed lines on maps represent approximate border lines for which there may not yet be full agreement.

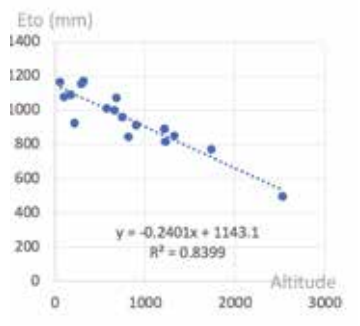
1.3 Climate data

The Republic of North Macedonia is in south-eastern Europe, on the western side of the Balkan Peninsula. It has a surface area of 25 713 km^2 and is bordered by Albania to the east, Serbia to the north, Bulgaria to the west, and Greece to the south. Despite the relatively small coverage, the country has a diverse climate due to its location and varied topography. The climate in the country has shown a reduction in annual rainfall and increase in average temperatures. (Sutton *et al.*, 2013)

Mean summer temperature moves from 20.6 to 24.3 degrees Celsius and winter temperature from 0.9 to 4.9 Celsius (World Bank, 2014), but it can reach extreme highs of more than 45 Celsius and lows of negative 30 Celsius in the winter (MOEPP, 2014) . In addition to the temperature variations, there is also an uneven temporal and spatial distribution of precipitation, with more favorable conditions in the western part of the country (World Bank, 2010). The annual rainfall amount ranges from 400 mm to about 1 000 mm, with an average of 733 mm (ibid). Climate change projections (Bergant, 2006) indicate that the average temperature will increase by 1 °C and 1.9 °C by 2025 and 2050, respectively. In addition, the mean precipitation for the corresponding periods is projected to decline by 3 percent and 5 percent, respectively, increasing the likelihood of more arid or drier climate conditions in Macedonia.

Climate data from the country were provided by the Hydro meteorological service (HMS) of North Macedonia, from 22 different meteorological stations form the network it manages. The data provided included reference evapotranspiration calculated using FAO's CROPWAT software for 17 meteorological as a 30–year monthly average; where from 15 the data range was for the period of 1981–2010 and from two stations the climatic data was with a 20–year range (1991–2010). In addition to the reference evapotranspiration, the HMS also provides 30–year monthly average precipitation data as well as daily temperature averages (Figure 4).

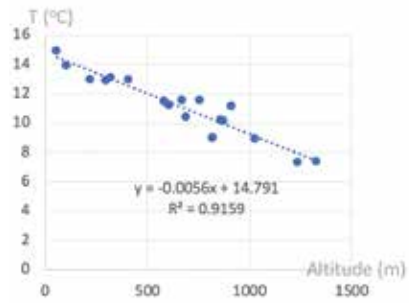
Figure 4 Reference **evapotranspiration** - annual sum versus elevation



CLIMATIC BASE LAYERS

The preparation of the climatic layers was done through linear regression analysis using elevation as a primary input variable for the climatic data. The output of the model was the equation from the linear regression as a function of the elevation and the climate parameter. The R2 for the ET^o was 0.83 and was considered a good correlation (Figure 5).

Figure 5 Average **temperature** versus elevation



From the average daily temperature it was also extracted the length of growing period (LGP) by counting the days which have larger temperature value of 5 °C and have continuity of at least five days. Also the LGP was calculated over bigger threshold values (6, 7, 8, 9 and 10 °C) for additional specific analyses. From this dataset was calculated the temperature sum of the same established thresholds. The correlation of these parameters also showed good results, 0.84 and 0.93 respectively (Figures 6 and 7).

Figure 6 **Length of growing period** versus elevation

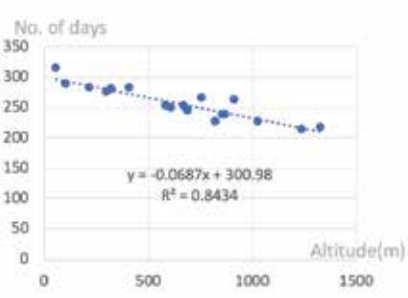
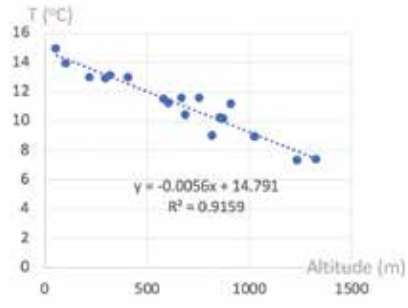
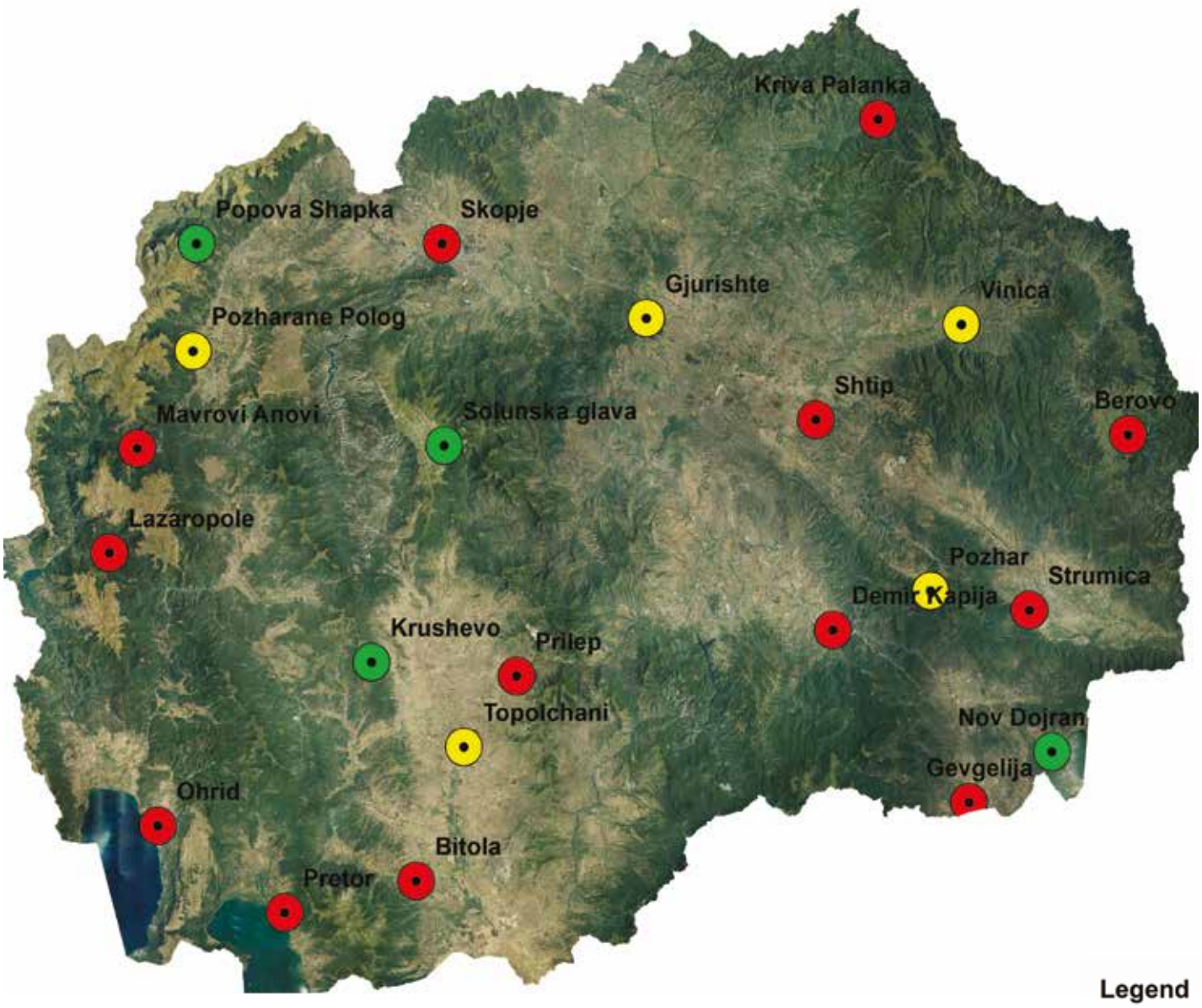


Figure 7 **Temperature sum** above 5 °C versus elevation



Based on the equations which are modeled by applying regression analysis of climate variables with the function of the elevation , continuous spatial layers for the whole country were produced in digital-GIS environment (maps follow).

Meteorological stations in North Macedonia

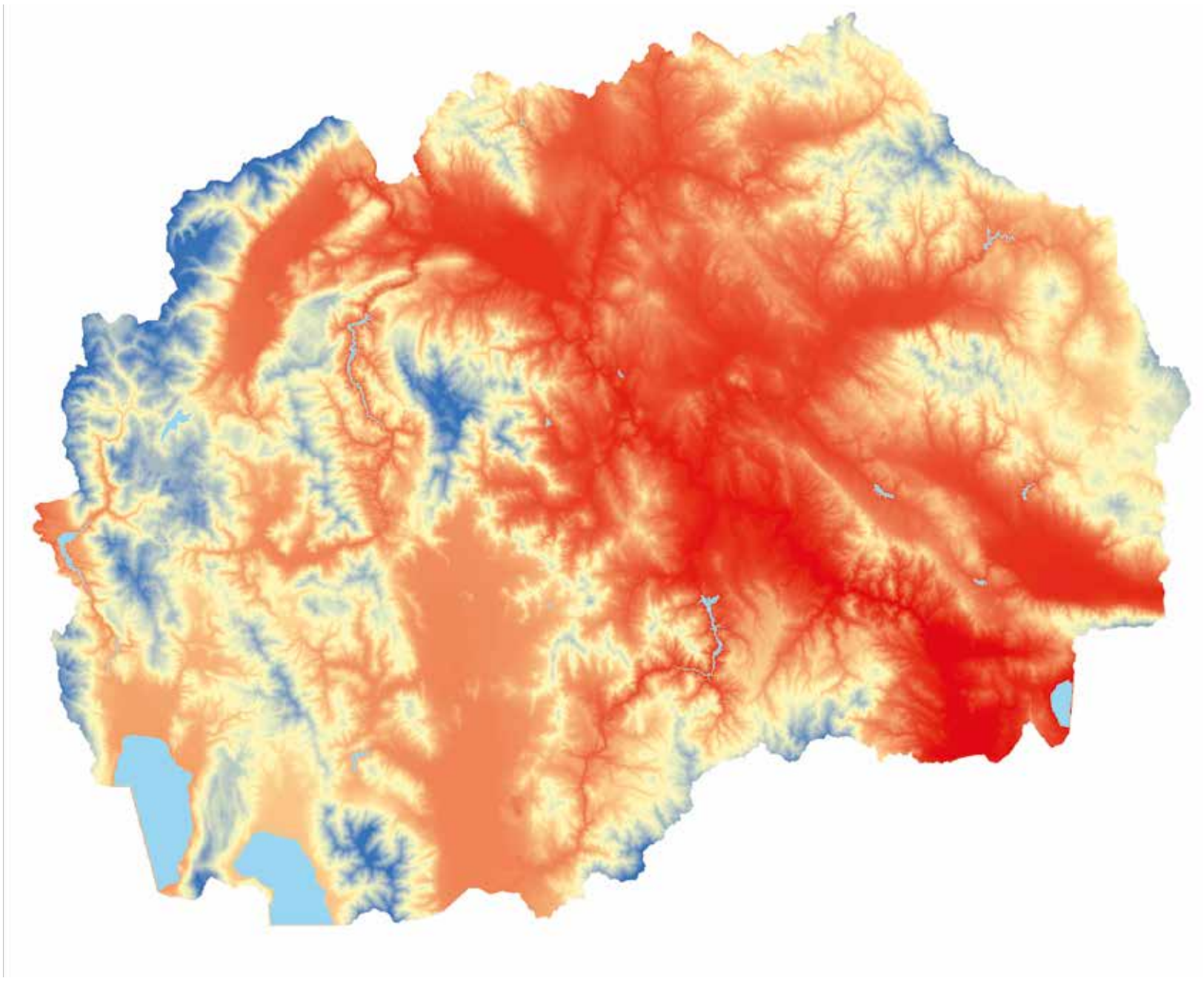


STATION	Dataset by HMS	STATION	Dataset by HMS	STATION	Dataset by HMS	STATION	Dataset by HMS	STATION	Dataset by HMS
Bitola[1]	ET°/T (daily average)	Ohrid	ET°/T (daily average)	Mavrovo	ET°/T (daily average)	Prilep	ET°/T (daily average)	Berovo	ET°/T (daily average)
Gevgelija	ET°/T (daily average)	Demir Kapija	ET°/T (daily average)	Popova Shapka	ET°	Skopje	ET°/T (daily average)	Kriva Palanka	ET°/T (daily average)
Lazaropole	ET°/T (daily average)	Strumica	ET°/T (daily average)	Solunska Glava	ET°	Shtip	ET°/T (daily average)	Pretor	ET°/T (daily average)
Pozhar	T (daily average)	Topolchani	T (daily average)	Pozharane Polog	T (daily average)	Gjurishte	T (daily average)	Vinica	T (daily average)
Nov Dojran[2]	ET°	Krushevo	ET°						

Source: Ivan Mincev (FAO).
Map conforms to UN world map, February 2019.
Dashed lines on maps represent approximate border lines for which there may not yet be full agreement.

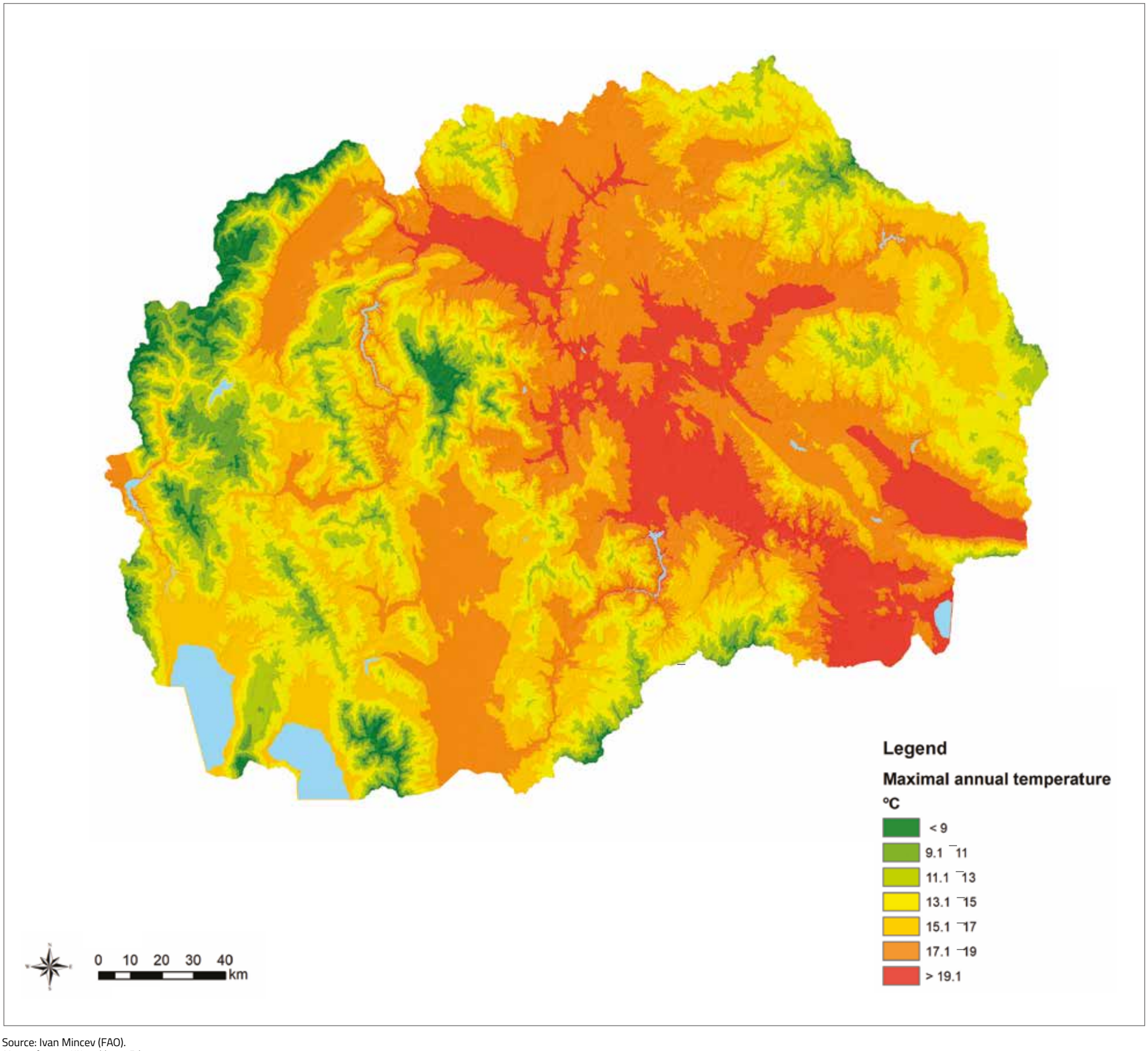
[1] Data range: 1981–2010
[2] Data range: 1991–2010

Potential evapotranspiration in North Macedonia



Source: Ivan Mincev (FAO).
Map conforms to UN world map, February 2019.
Dashed lines on maps represent approximate border lines for which there may not yet be full agreement.

Maximal annual temperature in North Macedonia



Source: Ivan Mincev (FAO).

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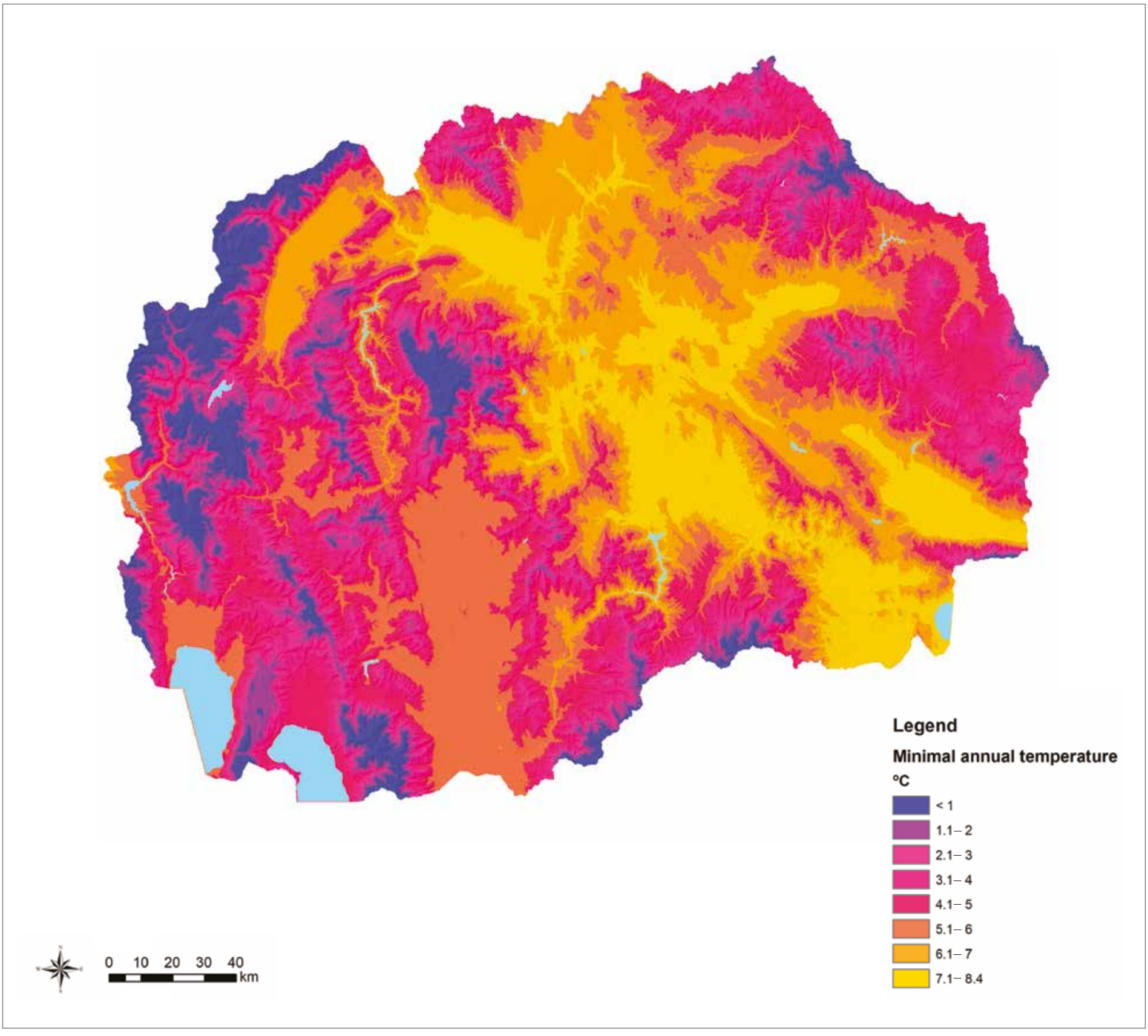
Minimal annual temperature in North Macedonia



Source: Ivan Mincev (FAO).
Map conforms to UN world map, February 2019.
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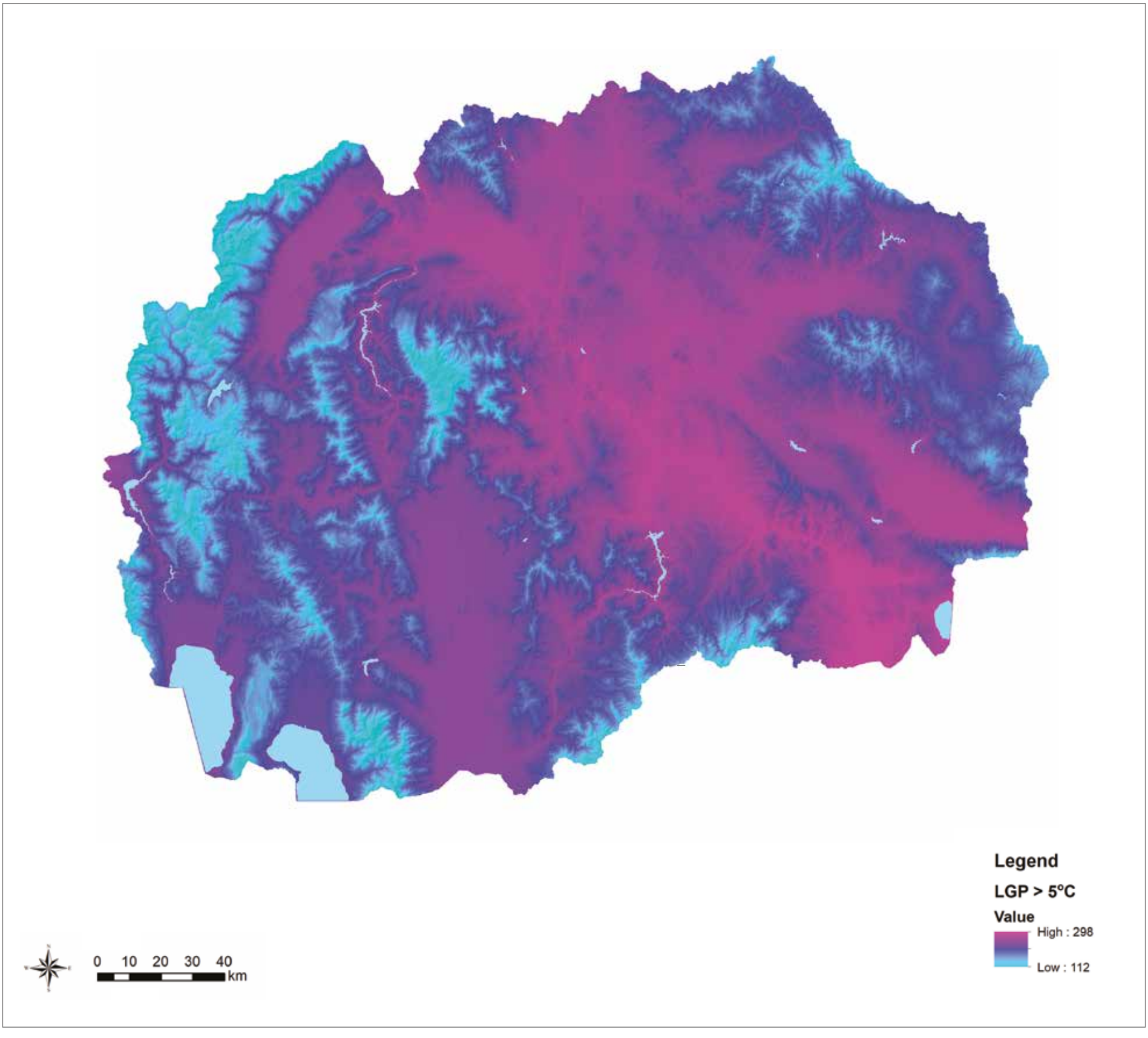
Length of growing period (1981–2010) in North Macedonia



Source: Ivan Mincev (FAO).
Map conforms to UN world map, February 2019.
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ARIDITY

The aridity index, which provides information about the climatic classes that are very important for crop productivity, was also calculated by applying the ratio between annual precipitation (P) and reference evapotranspiration (Et^o), which is calculated by method of Penman, taking into account atmospheric humidity, solar radiation, and wind (FAO, www.fao.org/3/t0122e/t0122e03.htm):

TABLE 1 - Aridity classes

Value	Class
< 0.03	Hyper-arid
0.03–0.2	Arid
0.2–0.5	Semi-arid
0.5–0.65	Dry sub-humid
> 0.65	Humid

Source: www.cgiar-csi.org/wp-content/uploads/2012/11/Global-Aridity-and- Global-PET-Methodology.pdf

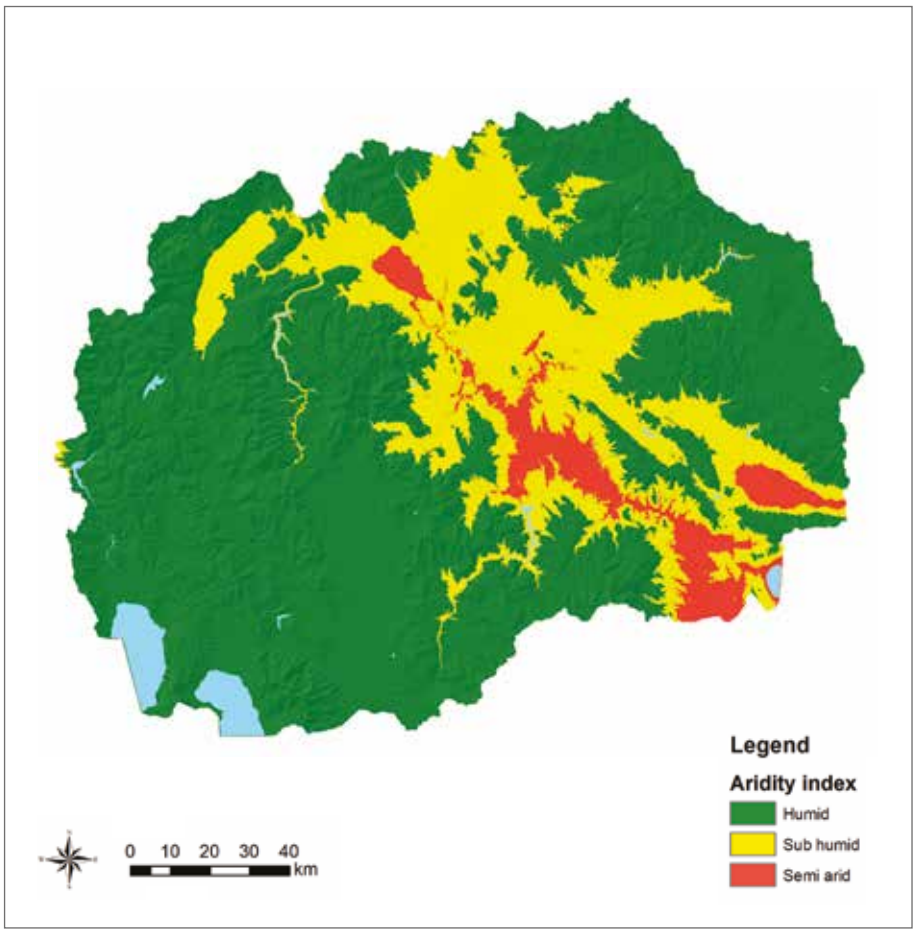
From the aridity index map it can be seen a nice differentiation of the classes semi-arid and dry sub-humid areas. These two classes delineate most of the agriculture areas in the central and southeast part of the country, which covers the driest areas. On the other hand, the humid class covers also some important agriculture areas in the western part of the country with more humid climatic condition. Therefore it was introduced another threshold of 0.85 in this classification which accounted for most of the agriculture area in the country. The values of the aridity index above 0.85 cover mountain-hilly and natural grassland areas, which are not suitable for agriculture because of the high slopes. The natural grasslands are situated above the tree line (approximately above 1 700 m) and are quite important for sheep herding in the summer. The last separation of classes was to divide the forest zone from the grassland zone. This was done using the elevation as a base layer with the threshold of 1 700 m with introduction of the aspect. When observing the aspect and the altitude of the forest line there can be observed clear difference on south and north aspect.

LAND COVER

The land cover map is another important data that is used in developing national agro -ecological zones (NAEZ) outputs. The output is developed by FAO Geospatial land cover experts by using FAO land cover classification system (LCCS) methodology and Sentinel-2 images; and then validated and improved by national land cover experts. According to the output, the Republic of North Macedonia is covered by;

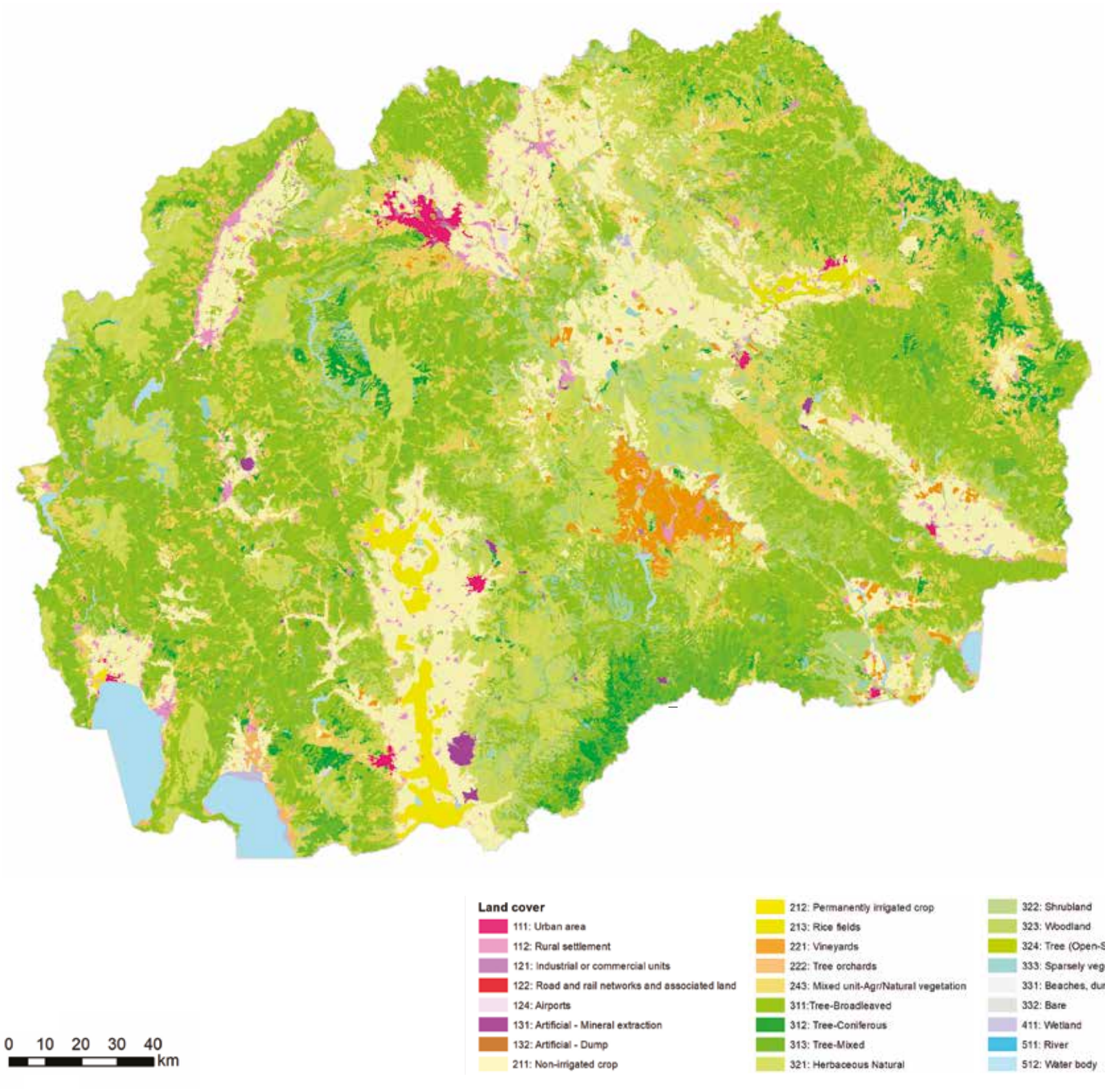
- tree 39 percent;
- natural vegetation 31 percent;
- agriculture 18 percent;
- NV & AG 8 percent;
- water 2 percent; and
- artificial areas 2 percent.

ARIDITY INDEX in North Macedonia



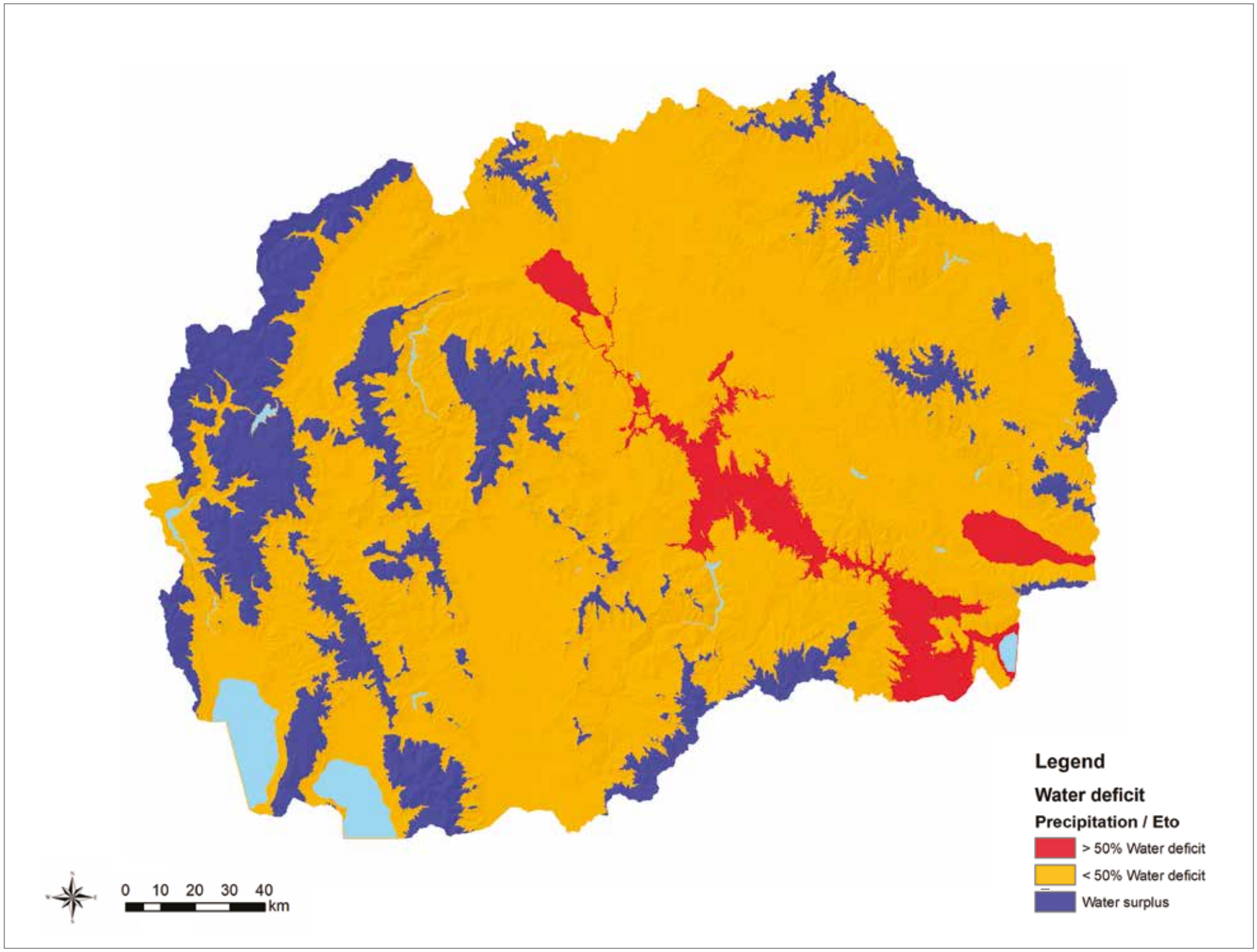
Source: Ivan Mincev (FAO).
Map conforms to UN world map, February 2019.
Dashed lines on maps represent approximate border lines for which there may not yet be full agreement.

Land cover in North Macedonia



Source: Gjorgij Gjorgjiev and Ilaria Rosati (FAO) - FAO LCCS methodology.
Map conforms to UN world map, February 2019.
Dashed lines on maps represent approximate border lines for which there may not yet be full agreement.

Water deficit in North Macedonia

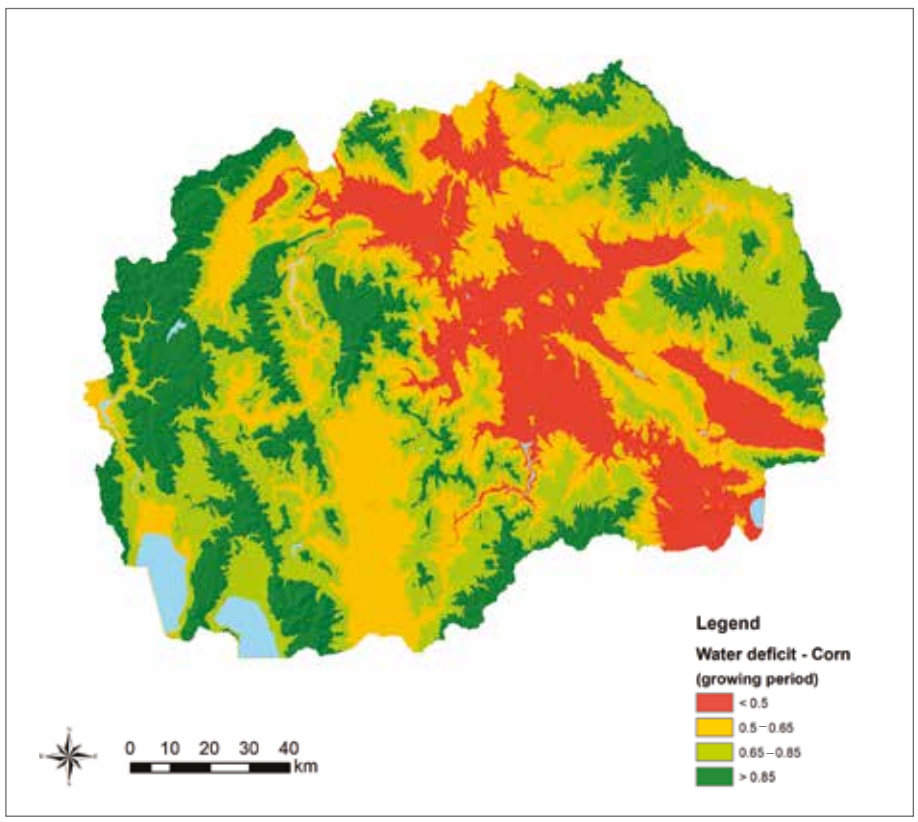


Source: Ivan Mincev (FAO).
Map conforms to UN world map, February 2019. Dashed lines on maps represent approximate border lines for which there may not yet be full agreement.

WATER DATA

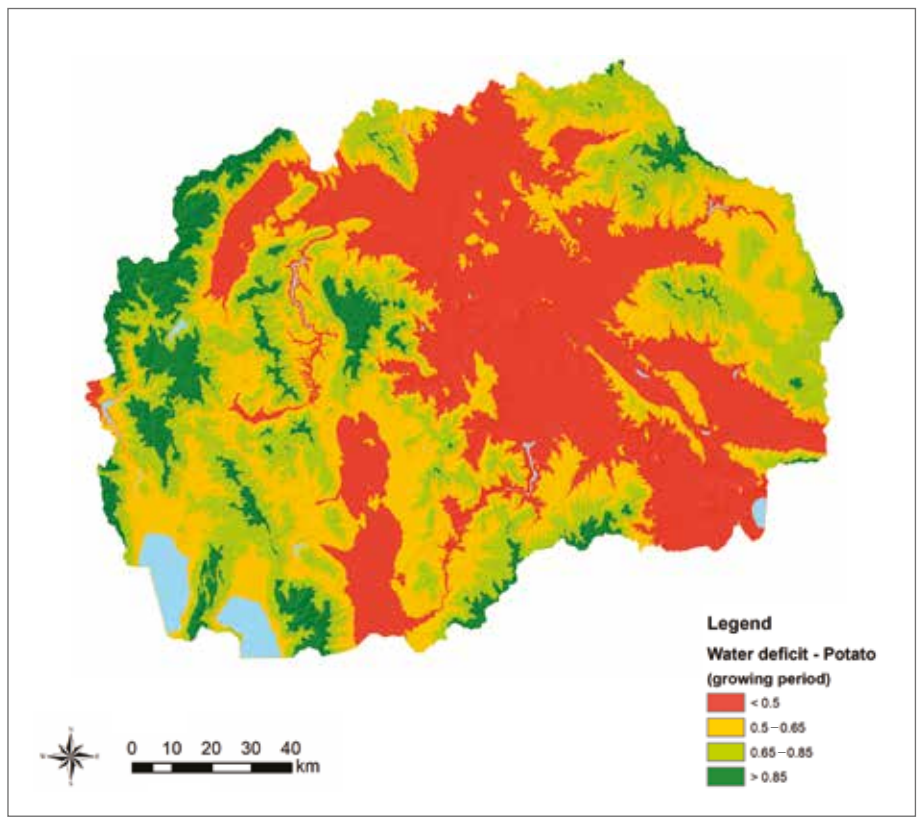
Irrigation data and underground water layers were not available. Therefore, we only used rainfall and evapotranspiration (ET^o) layers to calculate the water deficit map. According to the map on this page, only a small region (semi-arid climate zone) has a water deficit; the rest of the country has no constraints with the water availability. Additionally, water scarcity maps per crops per growing period are prepared and used in developing NAEZ crop suitability layers (examples on the following page).

CORN - Water deficit in North Macedonia



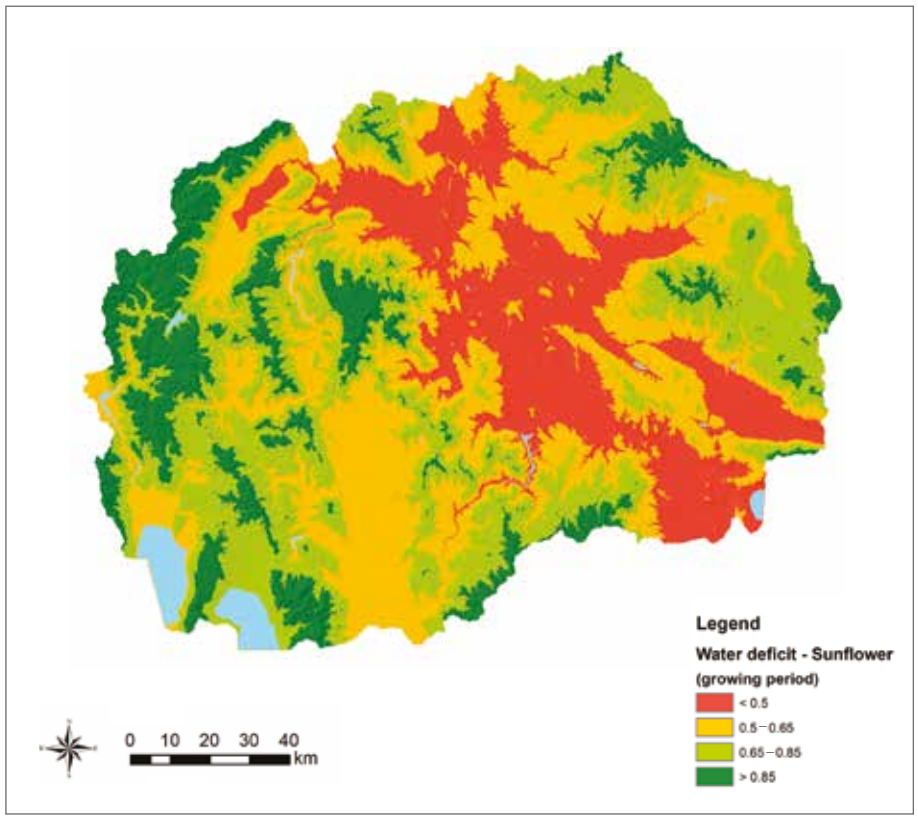
Source: Ivan Mincev (FAO).
Map conforms to UN world map, February 2019.
Dashed lines on maps represent approximate border lines for which there may not yet be full agreement.

POTATO - Water deficit in North Macedonia



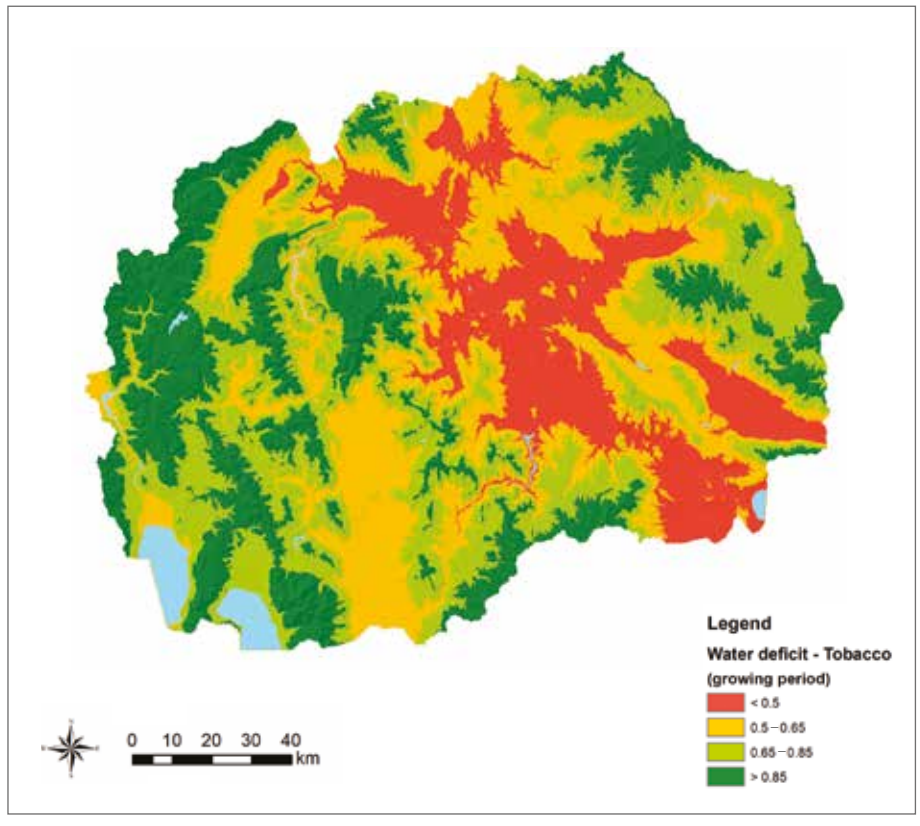
Source: Ivan Mincev (FAO).
Map conforms to UN world map, February 2019.
Dashed lines on maps represent approximate border lines for which there may not yet be full agreement.

SUNFLOWER - Water deficit in North Macedonia



Source: Ivan Mincev (FAO).
Map conforms to UN world map, February 2019.
Dashed lines on maps represent approximate border lines for which there may not yet be full agreement.

TOBACCO - Water deficit in North Macedonia



Source: Ivan Mincev (FAO).
Map conforms to UN world map, February 2019.
Dashed lines on maps represent approximate border lines for which there may not yet be full agreement.

2

Agro-climatic analysis

As part of the agro-ecological zoning process, agro-climatic zones for the country were developed based on the aridity Index map in combination with the elevation of the country to define five agro-climatic zones, the characteristics of which can be seen on the Table 2, and in the map that follows. The climatic zones were defined by adjusting the aridity index distribution with elevation and aspect in order to correct for forest and grassland delineation.

Figure 8 Agro-climatic zones in North Macedonia

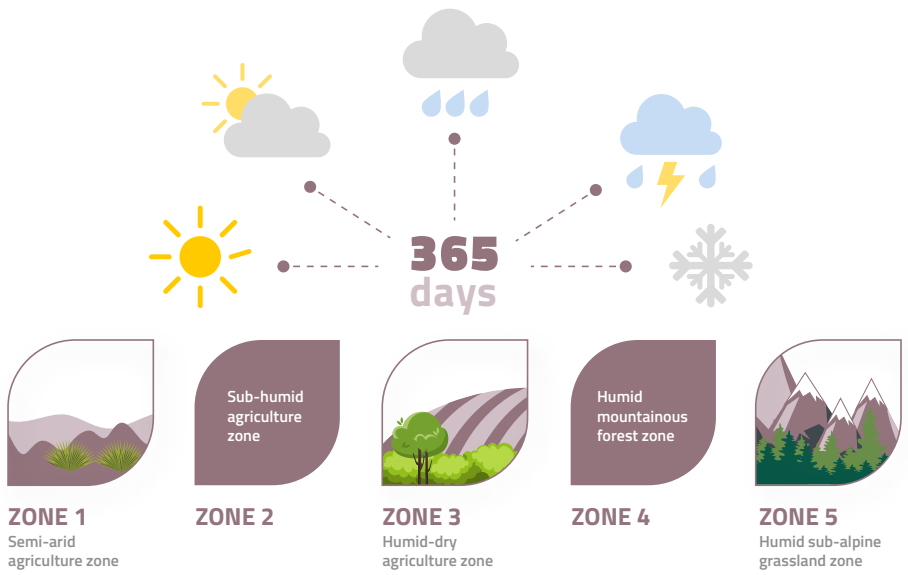
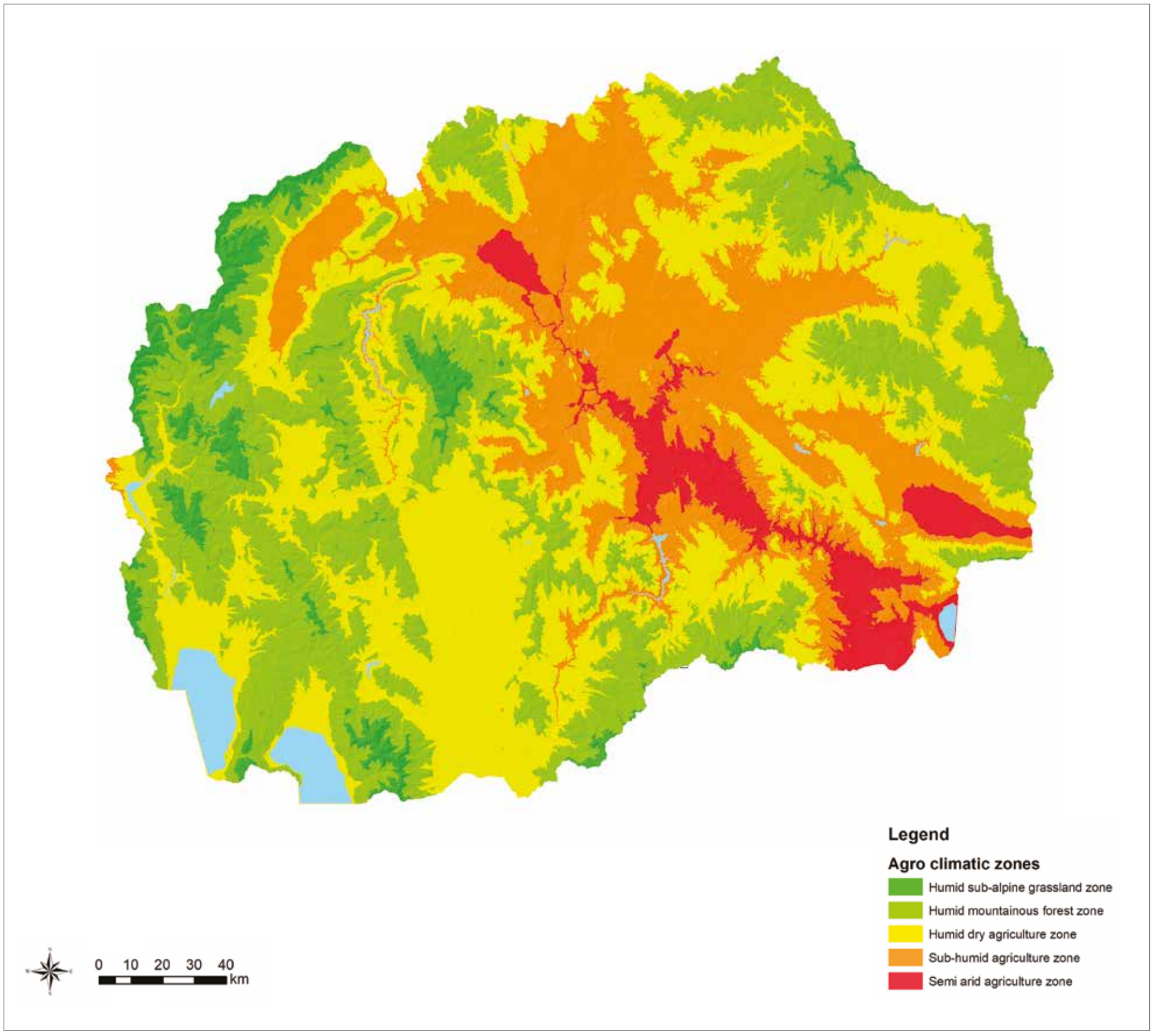


TABLE 2 - Agro-climatic zones characteristics

AGRO-CLIMATIC ZONE	Semi-arid agriculture zone	Sub-humid agriculture zone	Humid-dry agriculture zone	Humid mountainous forest zone	Humid sub-alpine grassland zone
Zone ID	1	2	3	4	5
Area (km²)	1 362.16	5 838.79	9 420.12	7 784.54	1 204.61
ETº min (mm)	1 072	982.5	902.6	723	481.9
ETº max (mm)	1 133.6	1 095.2	1 067.1	1 133.3	915.5
ETº average (mm)	1 101	1 048.6	968.9	848.5	676.9
Annual precipitation min (mm)	548.7	544	544.1	544	241.5
Annual precipitation max (mm)	631.8	591.9	726.8	1 008.9	1 014.4
Annual precipitation average (mm)	576.3	548.7	614.9	828.8	977.2
Temperature min (Celsius)	13.1	11	9.2	5	-0.6
Temperature max (Celsius)	14.6	13.7	13	14.6	9.5
Temperature average (Celsius)	13.8	12.6	10.7	7.9	3.9
LGP min (>5 deg)	280.6	255	232.2	180.8	111.8
LGP max (>5 deg)	298.3	287.3	279.2	298.2	235.9
LGP average (>5 deg)	288.9	273.9	251.1	216.7	167.6
Main soil type	Fluvisol 41% Regosol complexes 24%	Fluvisol 15% Regosol complexes 15% Vertisol complexes 17%	Cambisol complexes 21% Fluvisol 14%	Cambisol complexes 53% Leptoso complexes 19%	Mollic, umbric and rendzic leptosols 75%
Main soil texture	Sandy loam 38% Sandy clay loam 34% Loamy sand 24%	Sandy loam 43% Sandy clay loam 27% Loamy sand 24%	Sandy loam 52% Loamy sand 40%	Sandy loam 52% Loamy sand 46%	Sandy loam 65% Loamy sand 32%
Slope average (%)	9.8	18.6	25.4	39.4	41.7
Main problems and constraints	Very dry will low precipitation in the growing period	Very dry will low precipitation in the growing period			Sub-alpine climate, short growing period, degraded soils with shallow topsoil

Agro-climatic zones in North Macedonia



Source: Ivan Mincev and Ece Aksoy (FAO).
Map conforms to UN world map, February 2019.
Dashed lines on maps represent approximate border lines for which there may not yet be full agreement.

3

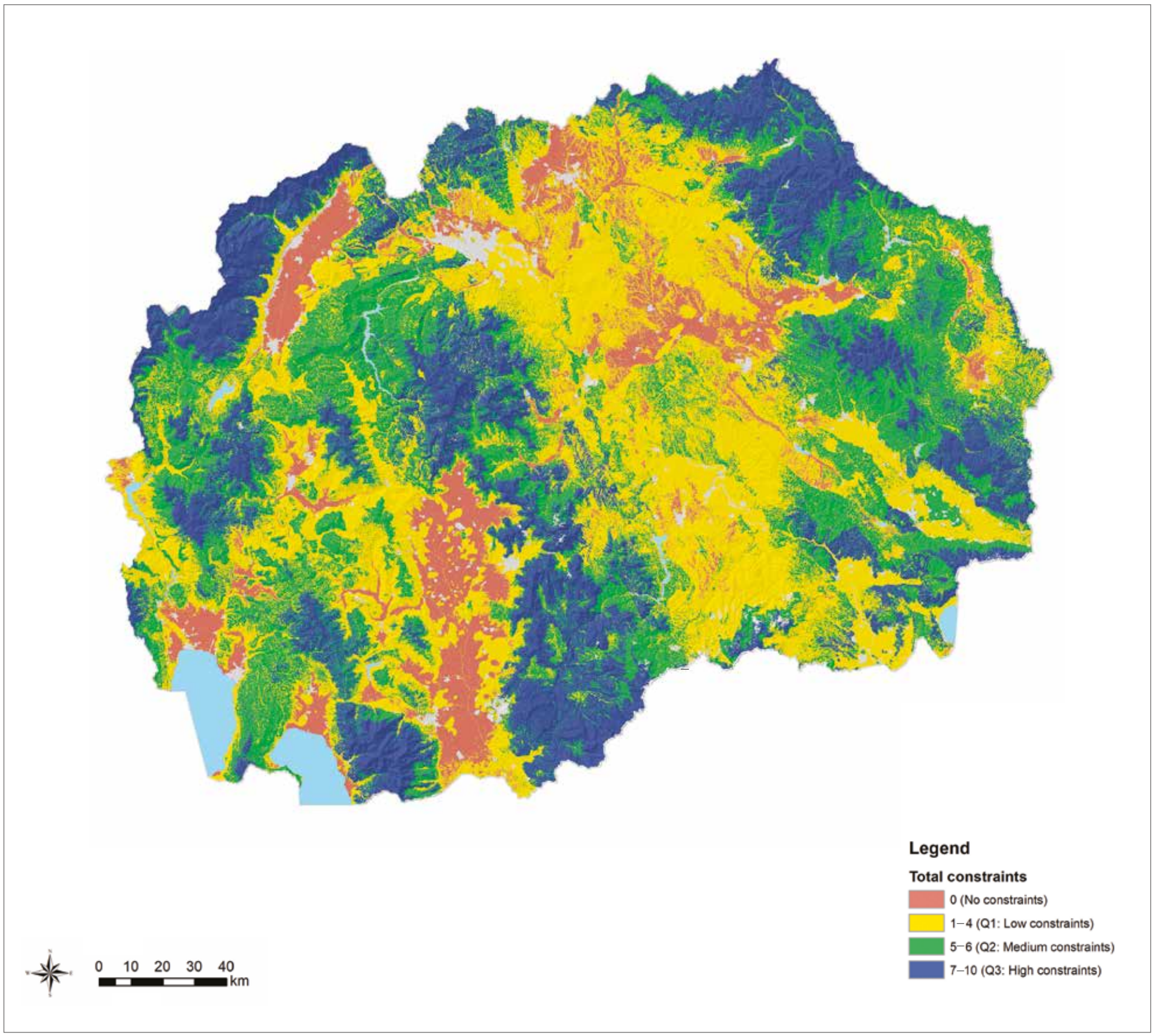
Agro-ecological zones

The delineation of the agro-ecological zones was made by combining agro-edaphic constraints with the five agro-climatic zones delineated in the country. In the process of delineating the agro-ecological zones, all agro-edaphic and biophysical constraints of the country in terms of limiting the agriculture productivity were considered, analyzed and mapped. Each of the constraints and their thresholds based on country dynamics and scientific literature references were considered together with the information on their intensity. All considered layers were reclassified and overlaid. Finally, eighteen agro-ecological zones, which give the information about the combination of similar limitations and potentials, were found out by overlaying the agro-climatic zones and agro-edaphic constraints layers.

TABLE 3 - Characteristics of the variables in each of the agro-ecological zones (average and/or majority)

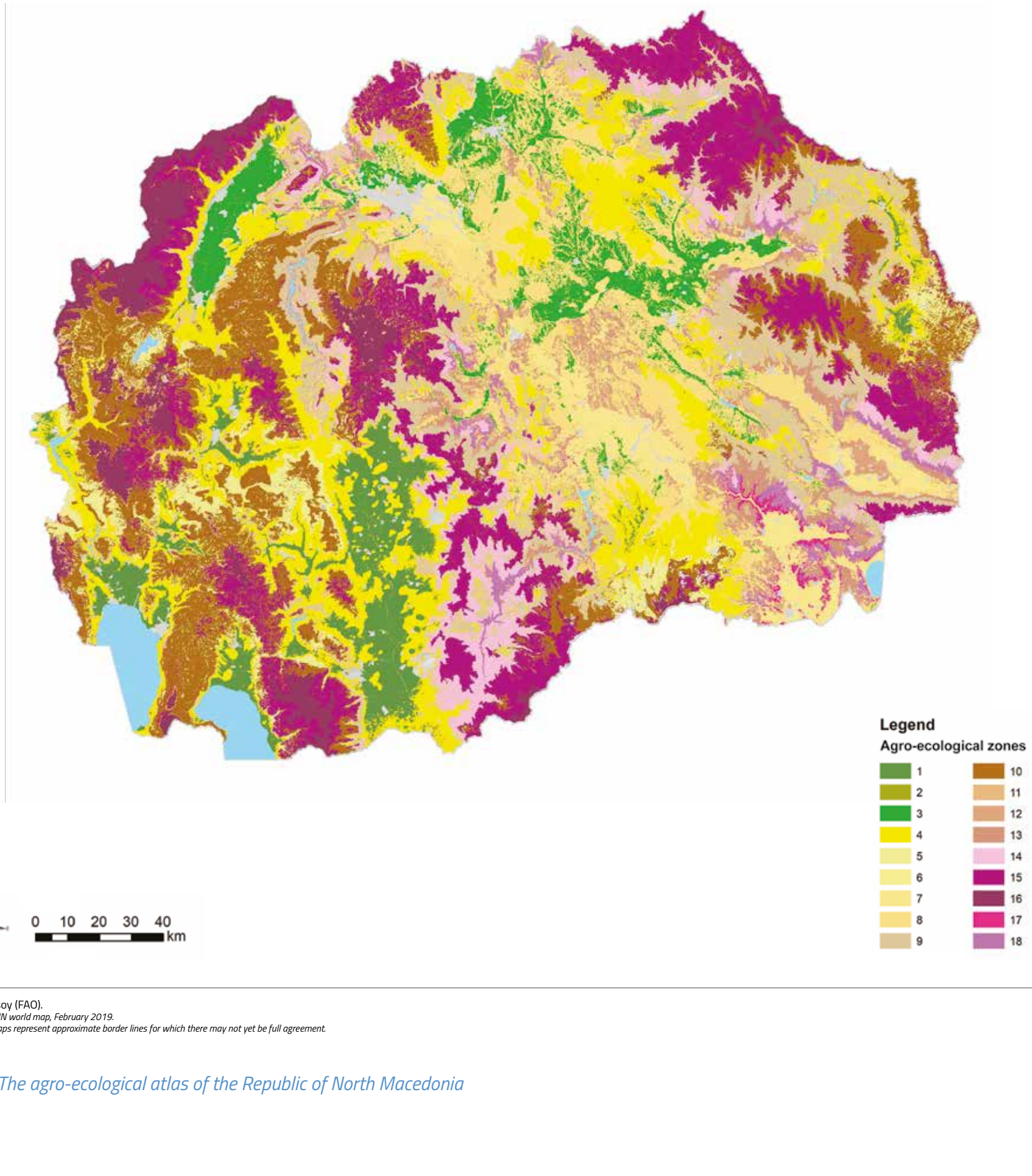
Agro -ecological zones	Agro -climatic zones	Contraint level	Soil depth average *(cm)*	Soil depth majority *(cm)*	Aridity average	SOC average	Slope average *(%)*	pH average	LGP5 average *(days)*	Frost risk free average *(days)*	Texture majority
1	Humid-dry	0	98.11	96.00	0.71	1.56	2.76	6.42	256.07	195.66	Sandy loam
2	Semi-arid	0	85.99	86.00	0.50	1.54	6.40	7.80	284.61	222.33	Sandy clay loam and sandy loam
3	Sub-humid	0	85.61	94.00	0.57	1.55	4.66	7.26	275.30	213.63	Sandy clay loam and sandy loam
4	Humid-dry	1	61.50	53.00	0.74	1.97	26.26	6.44	251.66	191.54	Sandy loam
5	Humid-forest	1	63.41	57.00	0.96	3.43	35.88	5.83	220.74	162.65	Sandy loam
6	Humid-grassland	1	62.66	53.00	1.24	5.17	27.39	5.70	182.20	126.63	Sandy loam
7	Semi-arid	1	76.54	83.00	0.47	1.34	8.12	7.61	289.22	226.64	Sandy clay loam and sandy loam
8	Sub-humid	1	60.82	55.00	0.58	1.57	20.09	7.27	273.98	212.40	Sandy clay loam and sandy loam
9	Humid-dry	2	45.93	48.00	0.76	2.20	40.10	6.36	249.31	189.34	Loamy sand and sandy loam
10	Humid forest	2	51.02	53.00	0.99	3.78	41.55	5.84	217.41	159.53	Loamy sand and sandy loam
11	Humid grassland	2	50.95	51.00	1.26	5.63	39.99	5.67	179.58	124.19	Sandy loam
12	Semi-arid	2	53.48	40.00	0.48	1.23	22.14	7.51	287.63	225.15	Loamy sand, sandy loam and silty clay loam
13	Sub-humid	2	43.63	44.00	0.59	1.83	37.28	6.94	272.27	210.81	Loamy sand and sandy loam
14	Humid-dry	3	33.93	38.00	0.76	1.98	40.21	6.37	248.39	188.49	Loamy sand
15	Humid forest	3	44.78	45.00	1.01	3.28	43.70	5.58	214.85	157.14	Loamy sand
16	Humid grassland	3	44.78	35.00	1.36	6.04	44.41	5.28	166.76	112.20	Loamy sand and sandy loam
17	Semi-arid	3	44.35	39.00	0.47	1.51	33.70	6.97	288.65	226.11	Loamy sand
18	Sub-humid	3	34.31	37.00	0.59	1.69	40.77	6.78	271.87	210.43	loamy sand
Constraint			< 50	< 50	< 0.5		> 15	< 5.5	< 179	< 179	Loamy sand, sandy loam and sandy clay loam

Total constraints in North Macedonia



Source: Ece Aksoy (FAO).
Map conforms to UN world map, February 2019.
Dashed lines on maps represent approximate border lines for which there may not yet be full agreement.

Agro-ecological zones in North Macedonia



Source: Ece Aksoy (FAO).
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4

Crop norms, productivity and economics

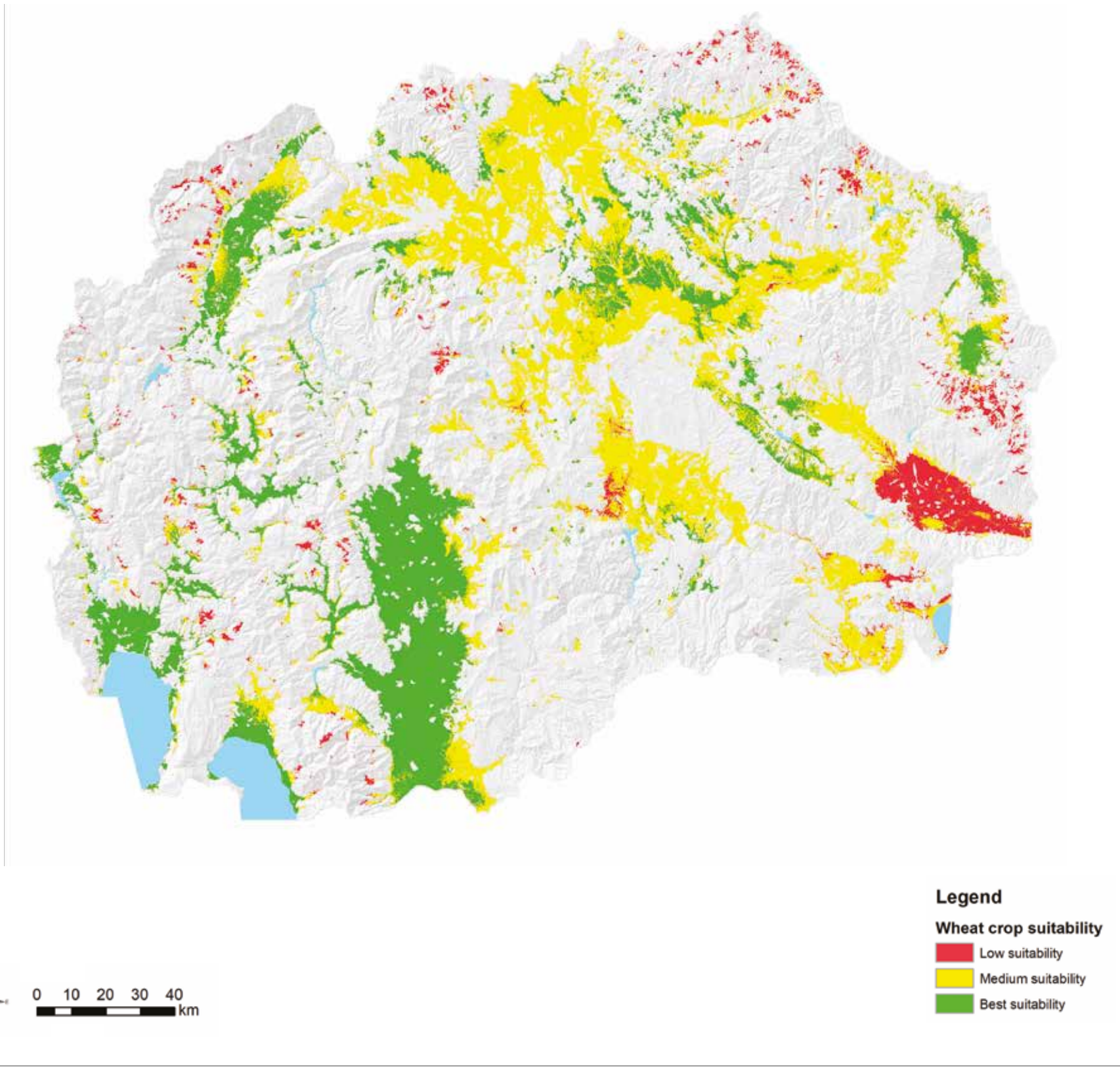
For the needs of the country, the members of the technical working group selected twelve crops to be analyzed in terms of agro-ecological suitability. However, crop norms and constraints data, which is provided by the Agricultural Faculty of Macedonia, for only ten of the crops were available as presented in the Table 4.

Crop suitability layers were prepared based on this crop information by reclassifying and overlaying for each of the crops. The final layers are masked out by using forest (natural vegetation tree dominated area. Codes: 311, 312, 313, 33fp and 324) and natural vegetation–grassland (natural vegetation grassland. Codes: 321, 322, 323 and 333) masks from the high-resolution Sentinel-2 based land cover map by LCCS methodology of FAO. By matching the optimal crop norm condition given in the table, the most suitable areas for production of the crops were developed as seen in the maps that follow.

TABLE 4 - Optimal crops norms conditions

CROP	Temperature max Jume *(°C)*	Soil depth *(m)*	Soil pH	Soil texture	LGP Spring	Aridity index (rainfall and ET°) April-June
Wheat	23–27	> 0.9	6–8.2	Sandy loam silty clay loam	> 100	> 0.5
Corn	24–28	> 0.75	5.8–7.8	Sandy loam silty clay loam	> 120	> 0.5
Barley	18–24	> 0.5	6.2–8	Sandy loam silty clay loam	> 100	> 0.5
Sunflower	18–26	> 0.8	6.2–8	Sandy clay loam to clay	> 140	> 0.5
Potato	24–28	> 0.6	5–6.7	Sandy loam to silty clay loam	> 120	> 0.5
Tomato	23–28	> 0.75	6–7.6	Loamy sand to silty clay loam	> 150	> 0.5
Pepper	23–28	> 1	6–7.5	Loamy sand to silty clay loam	> 150	> 0.5
Grape	25–32	> 0.75	5.5–7	Loamy sand to silty clay loam	> 150	> 0.5
Rice	28–32	> 0.4	5.5–7.5	Clay loam to clay	> 150	No aridity, because water availability is a must for rice production
Alfalfa	25–32	> 0.7	6.0–8.0	Loamy sand to silty clay loam	> 150	> 0.5

WHEAT crop suitability in North Macedonia



Source: Ivan Mincev (FAO).
Map conforms to UN world map, February 2019.
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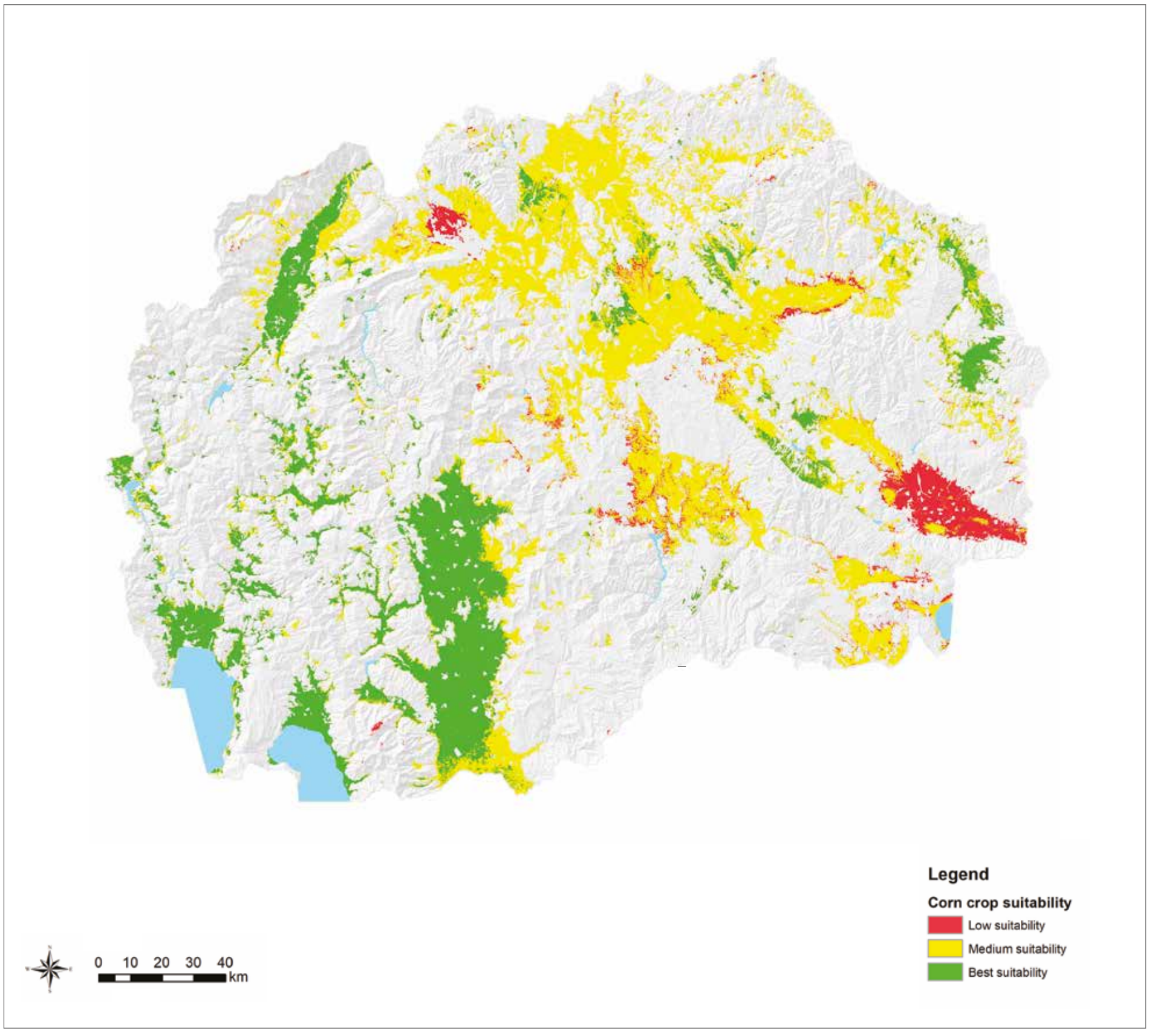
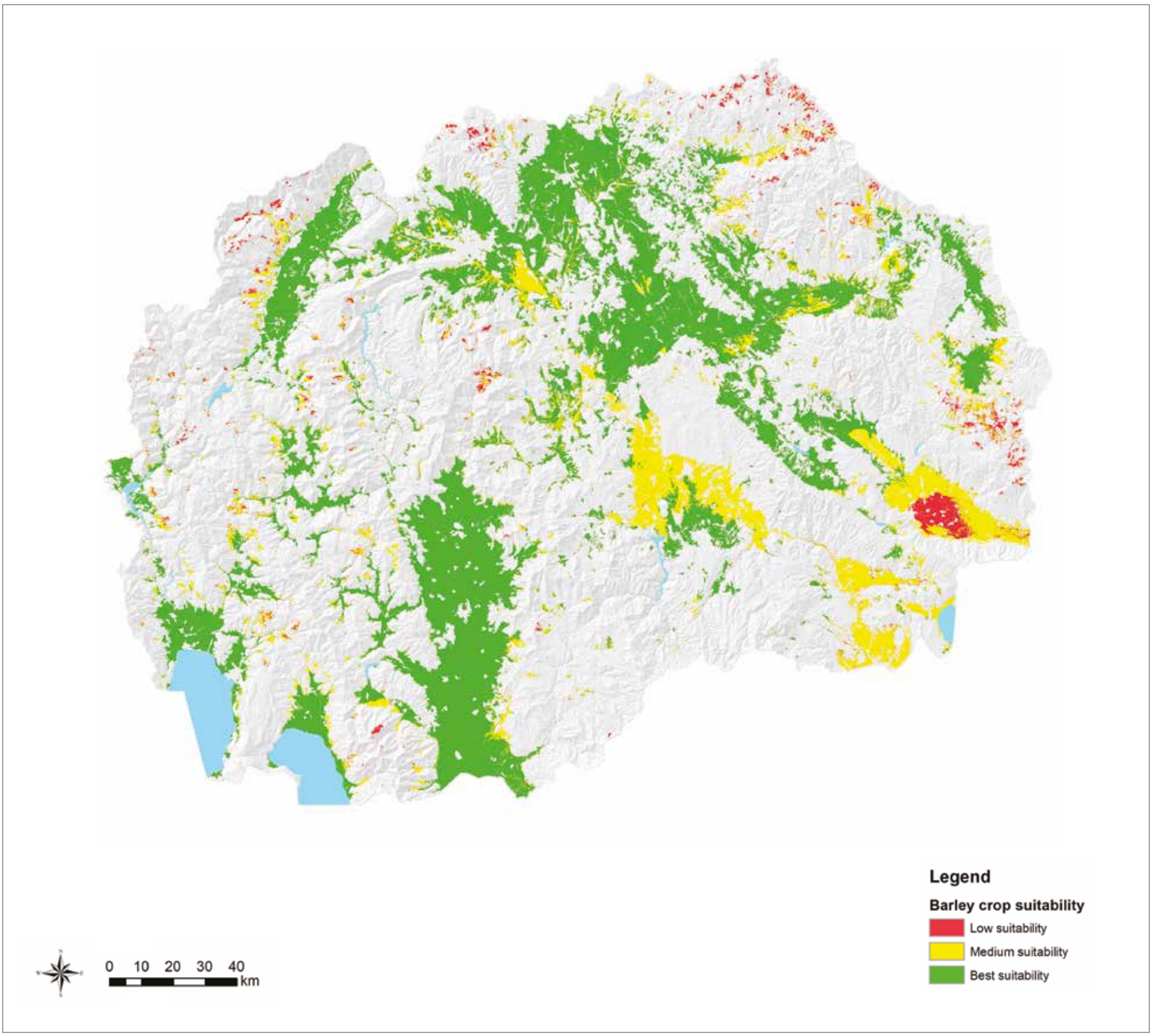
CORN crop suitability in North Macedonia



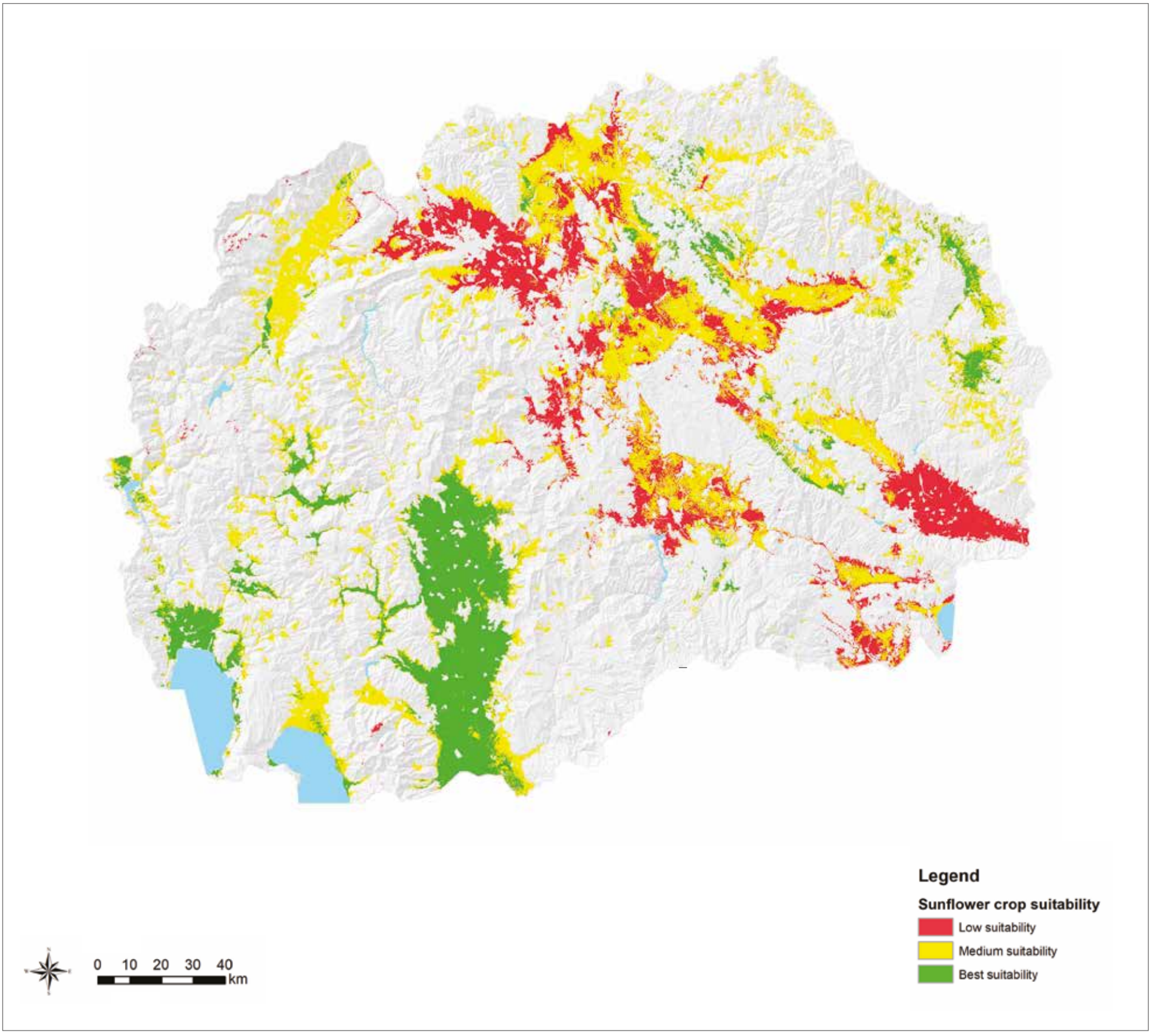
Source: Ivan Mincev (FAO).
Map conforms to UN world map, February 2019.
Dashed lines on maps represent approximate border lines for which there may not yet be full agreement.

BARLEY crop suitability in North Macedonia



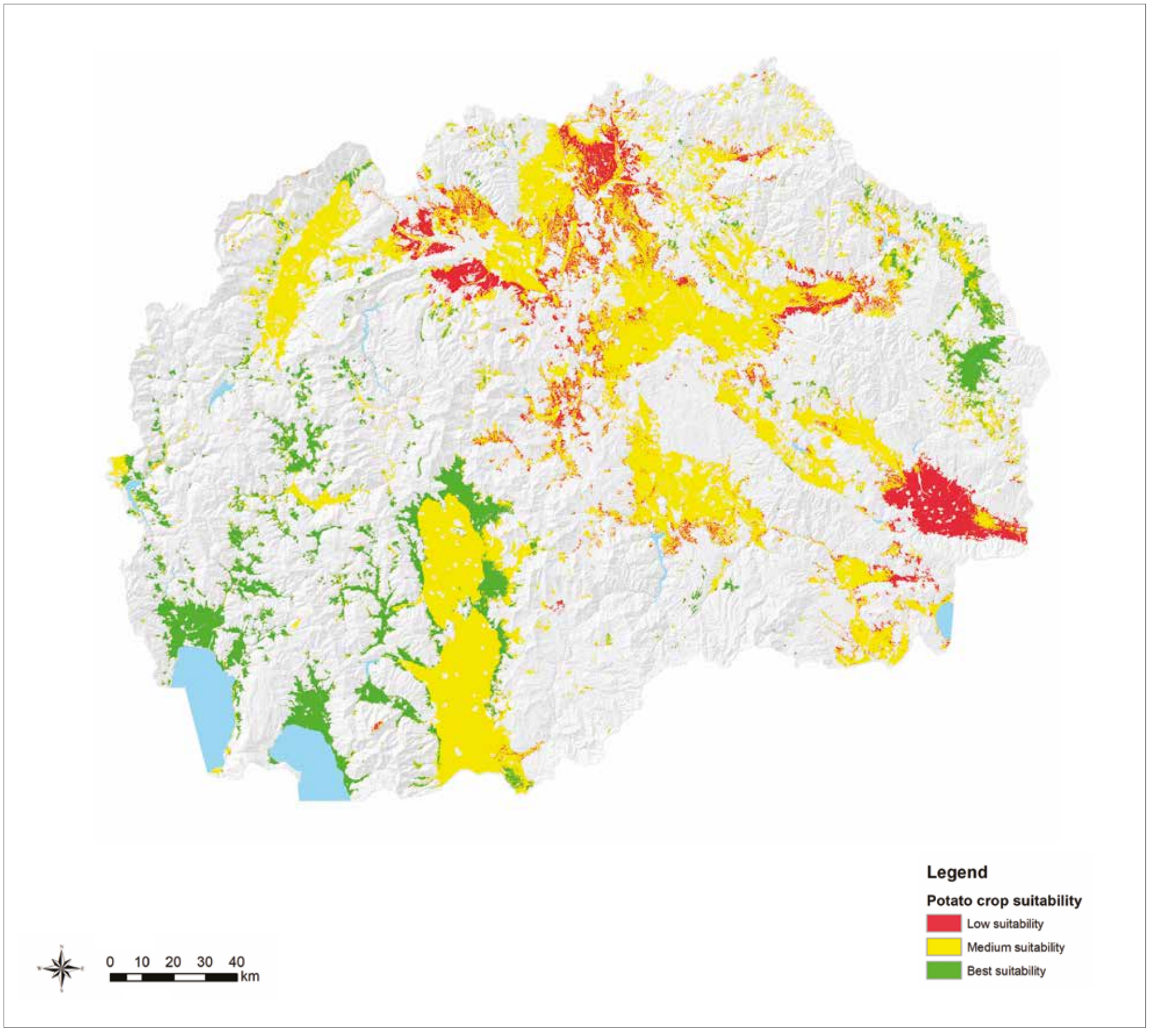
Source: Ivan Mincev (FAO).
Map conforms to UN world map, February 2019.
Dashed lines on maps represent approximate border lines for which there may not yet be full agreement.

SUNFLOWER crop suitability in North Macedonia



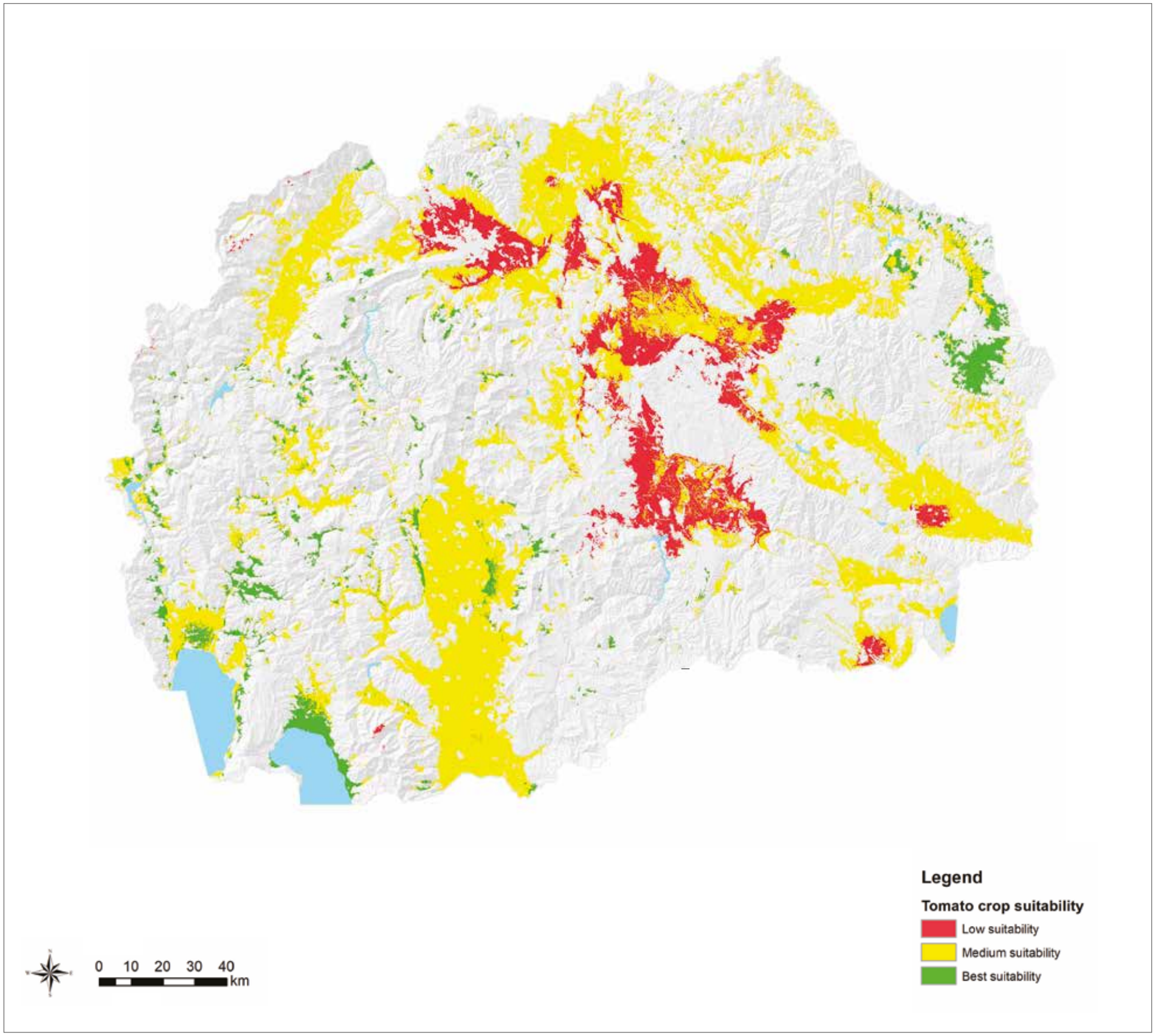
Source: Ivan Mincev (FAO).
Map conforms to UN world map, February 2019.
Dashed lines on maps represent approximate border lines for which there may not yet be full agreement.

POTATO crop suitability in North Macedonia



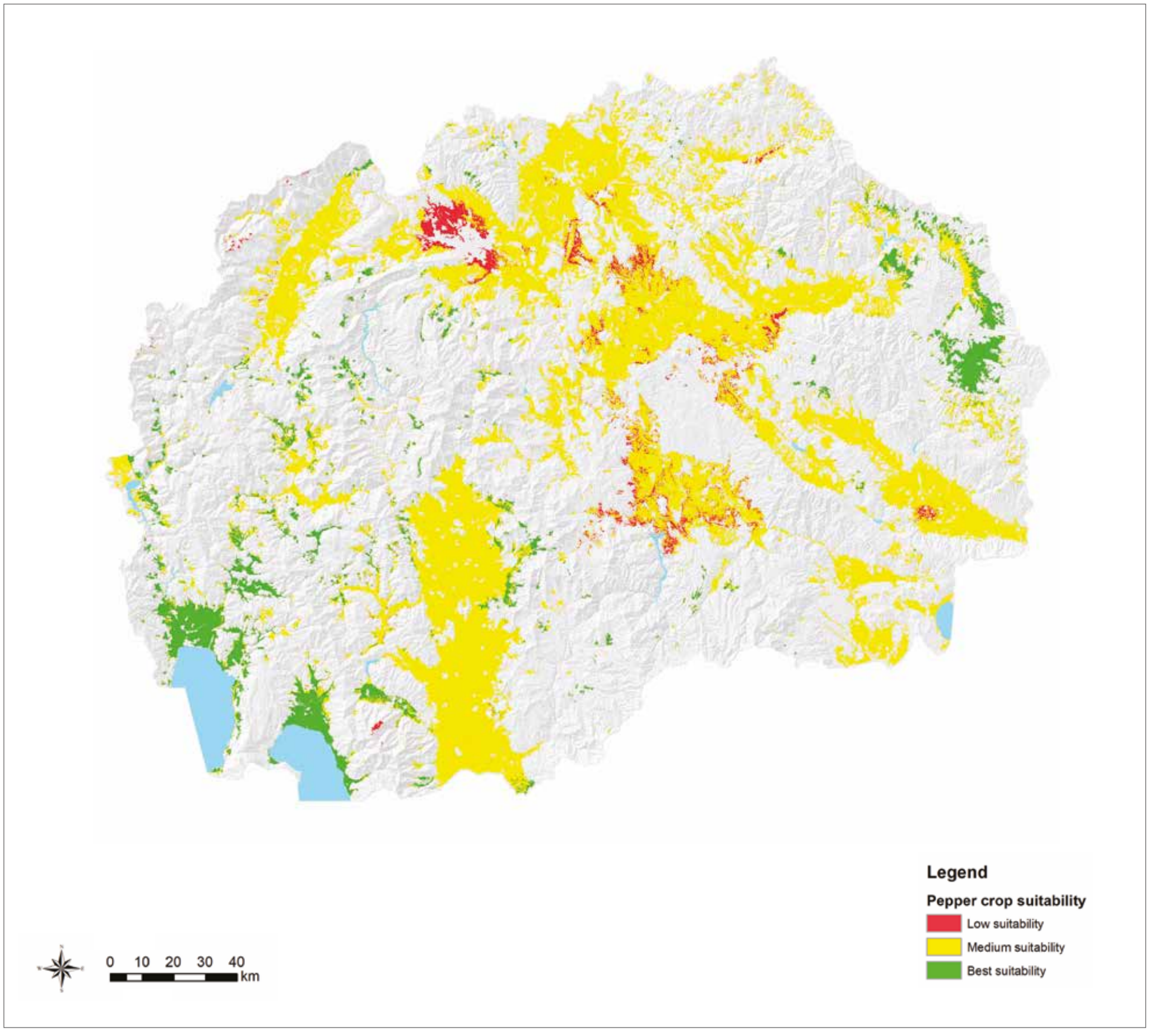
Source: Ivan Mincev (FAO).
Map conforms to UN world map, February 2019.
Dashed lines on maps represent approximate border lines for which there may not yet be full agreement.

TOMATO crop suitability in North Macedonia



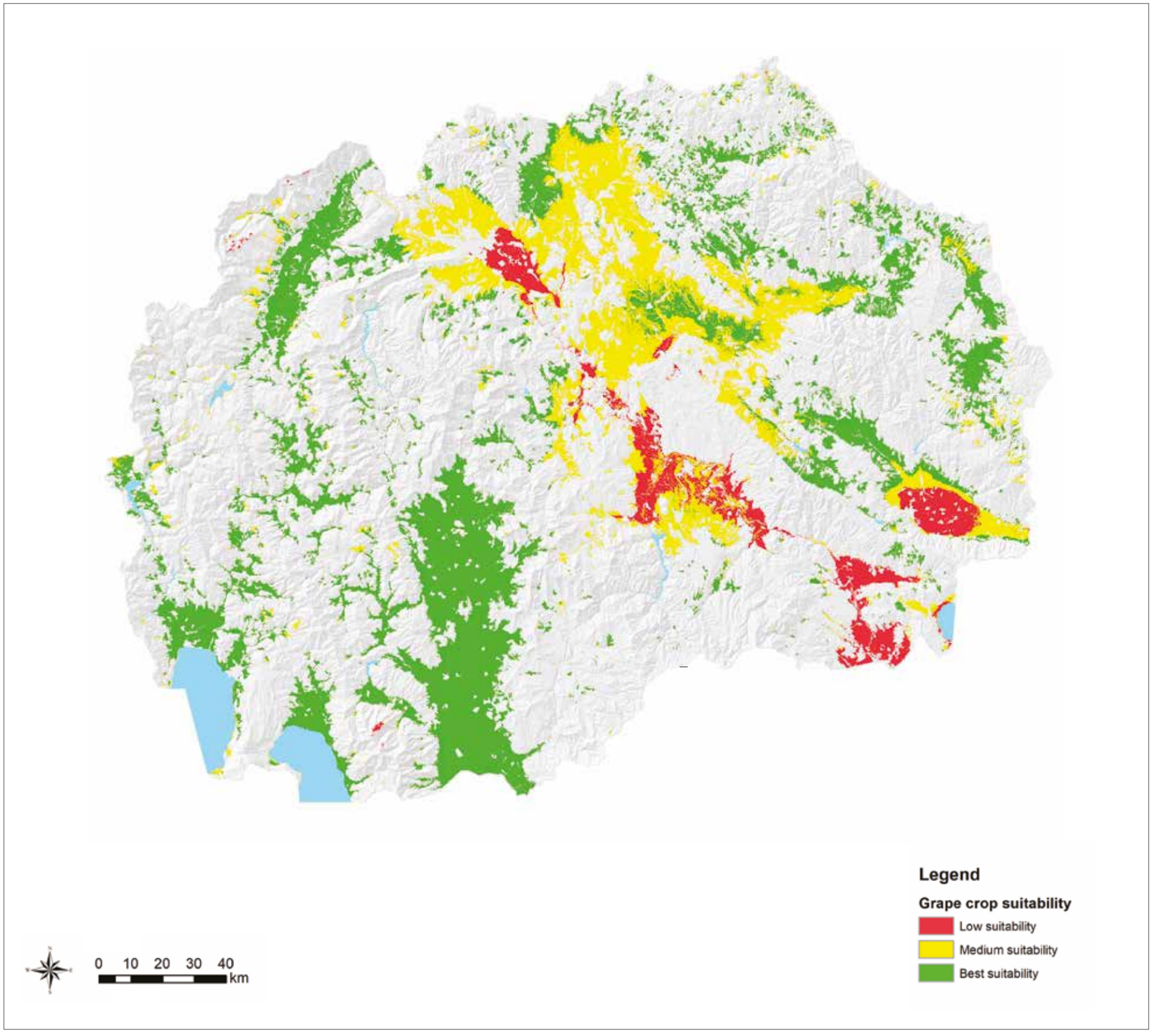
Source: Ivan Mincev (FAO).
Map conforms to UN world map, February 2019.
Dashed lines on maps represent approximate border lines for which there may not yet be full agreement.

PEPPER crop suitability in North Macedonia



Source: Ivan Mincev (FAO).
Map conforms to UN world map, February 2019.
Dashed lines on maps represent approximate border lines for which there may not yet be full agreement.

GRAPE crop suitability in North Macedonia



Source: Ivan Mincev (FAO).
Map conforms to UN world map, February 2019.
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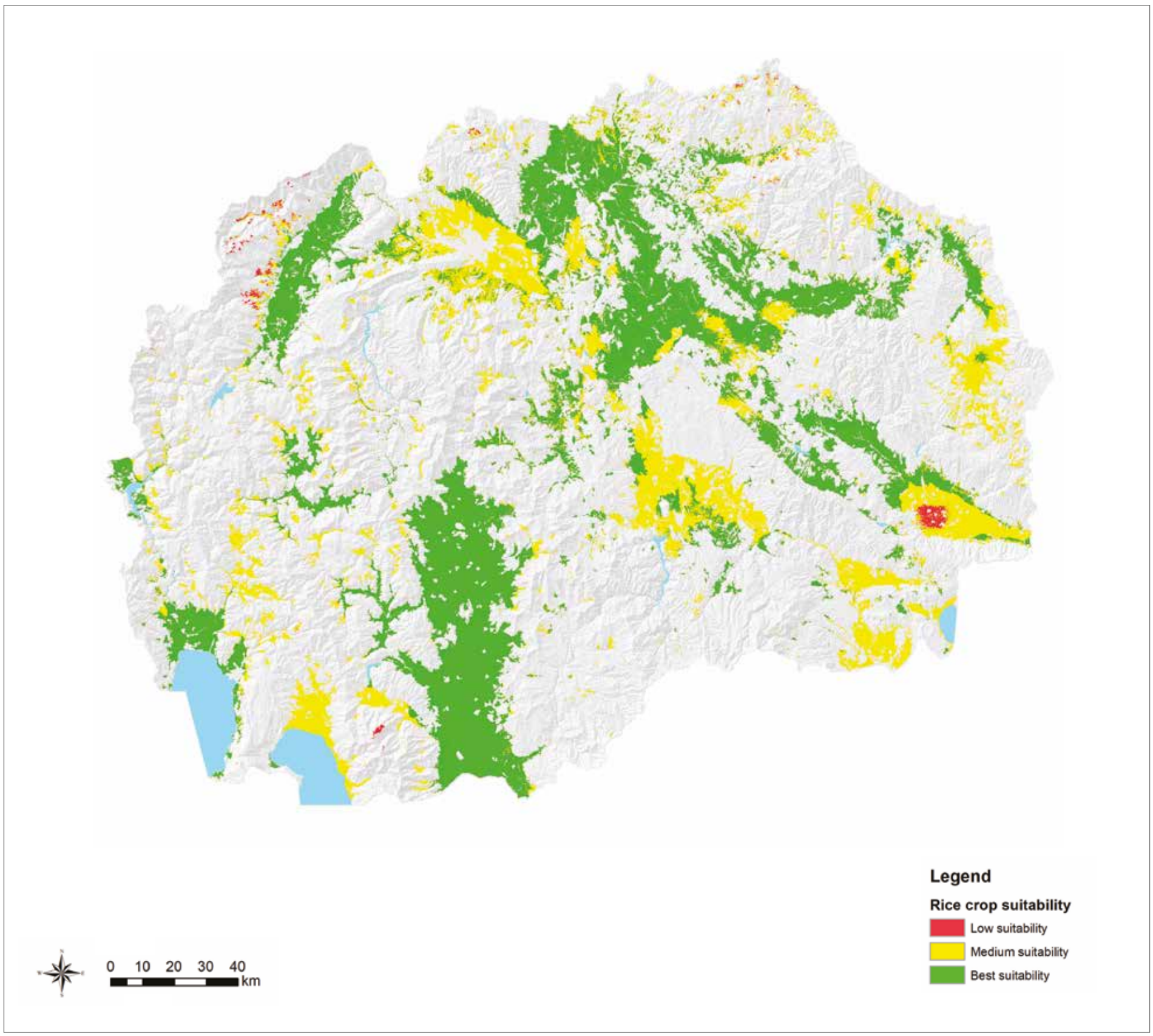
RICE crop suitability in North Macedonia



Source: Ivan Mincev (FAO).
Map conforms to UN world map, February 2019.
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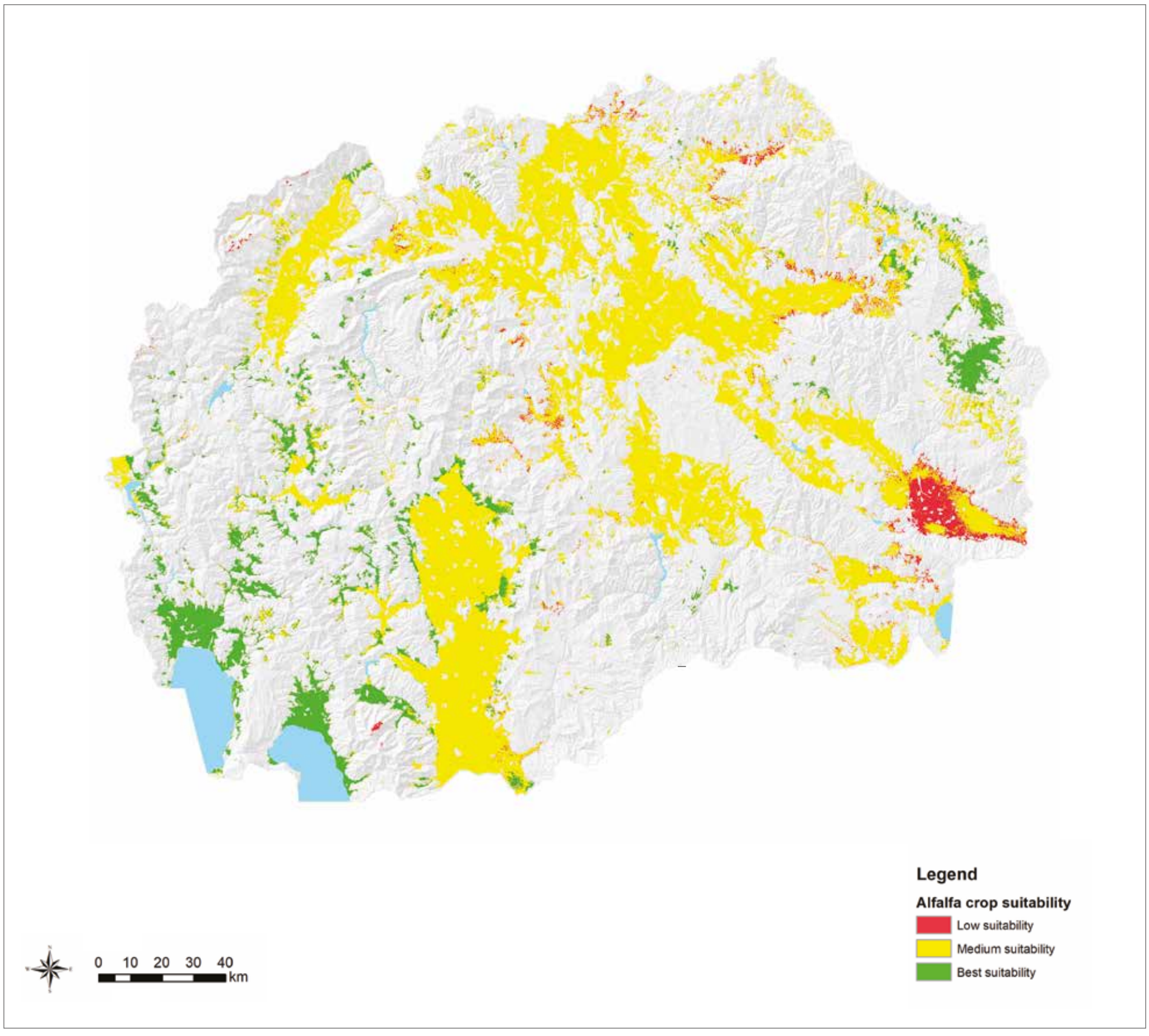
ALFALFA crop suitability in North Macedonia



Source: Ivan Mincev (FAO).
Map conforms to UN world map, February 2019.
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4.1 Projected crop yields and gross income

The projected crop yields were estimated based on adjusting existing country data on yields, by using average data for the selected crops. The crop yields were initially calculated based on 5-years crop statistics of municipalities (FAOSTAT). Yield (hg/ha) averages (2007–2016) is used for potato and rice data. The rest is based on the agricultural statistics of the country (2014–2018)) as seen in Table 5.

TABLE 5 - Gross income projection of crops' spatial distribution

CROP	Min *(kg/ha)*	(Min+Mean) /2	Mean *(kg/ha)*	0.75 of max	0.9 of max	Max *(kg/ha)*
	1	2	3	4	5	6
Wheat	2 060	2 573	3 085	3 635	4 362	4 847
Corn	1 275	2 705	4 134	6 434	7 720	8 578
Barley	1 160	1 875	2 590	3 057	3 668	4 076
Sunflower	2 848	9 023	15 197	28 477	34 172	37 969
Potato	2 844	7 111	14 222	21 333	25 600	28 444
Tomato	2 660	10 563	18 466	67 223	80 667	89 630
Pepper	986	7 553	14 119	33 964	40 756	45 285
Grape	1 556	5 001	8 445	16 442	19 731	21 923
Rice	1 183	2 957	5 913	8 870	10 643	11 826
Alfalfa	1 840	3 670	5 499	10 106	12 128	13 475

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The agro-ecological suitability of the selected crops were assigned per each of the suitability classes (1 to 6) as yield potentials where the suitability of the crops is lower so is the projected yield, without accounting for intense human intervention.

The gross income projection spatial distribution for the crops, were then calculated as potential income per hectare:

Potential income MKD/Ha= Potential yield (Kg)*Farm gate price (MKD/kg)

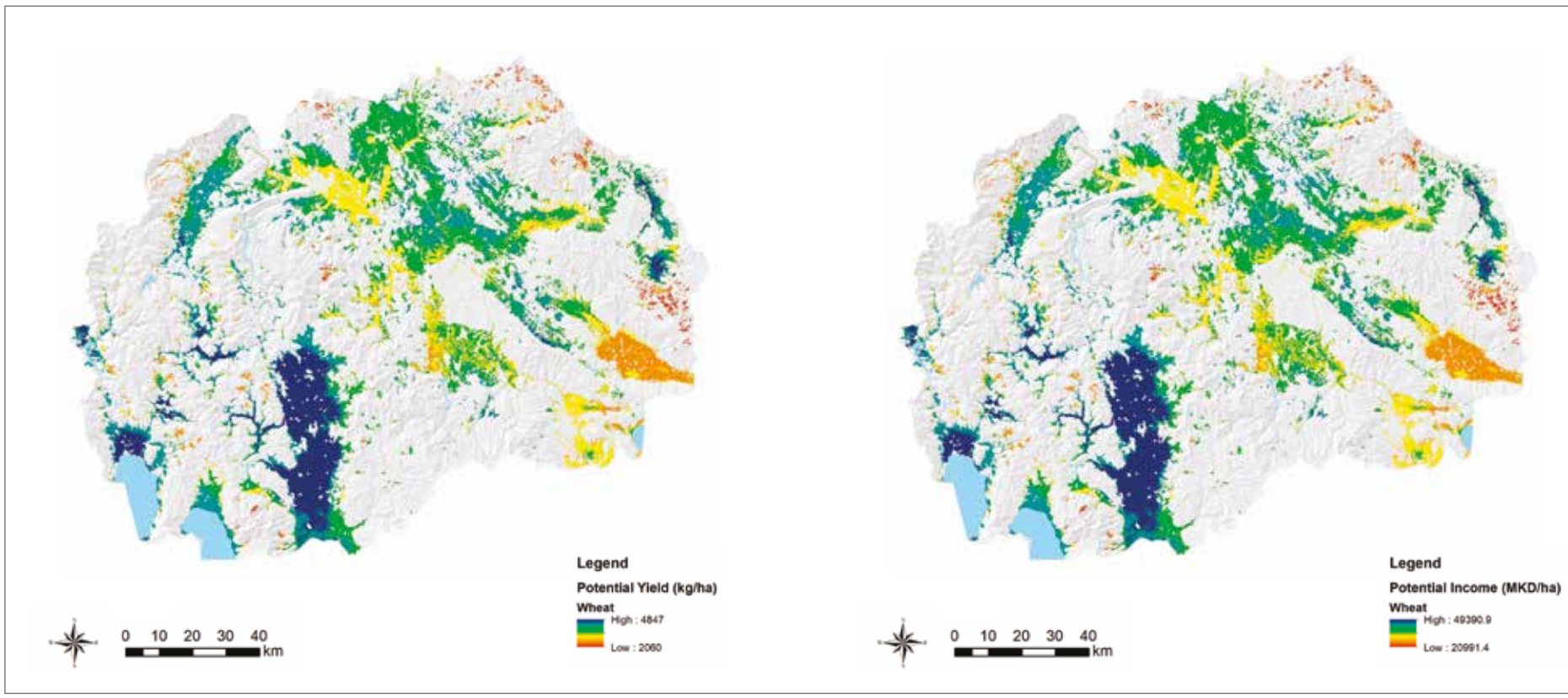
This allow presenting the potential economic variability of the crops in the country distributed across regions based on realistic prices. The price were calculated from the annual statistic yearbook of the state statistics office for 2017 and 2018, based on the total purchased products registered at wholesale and the total output value of the crops registered at wholesale by the official state statistics (Table 6).

In the maps that follow only the distribution of the income for the selected crops based on average price for the year 2018 are presented, since 2019 data is not yet available. However, in further economic modeling the same income distribution can be projected either using price indices corrections or real time prices.

TABLE 6 - Value of the crops 2017–2018

CROP	Price 2017 *(MKD)*	Price 2018 *(MKD)*
Wheat	9.53	10.19
Corn	9.53	8.52
Barley	9.22	9.02
Sunflower	18.95	17.16
Potato	18.74	14.44
Tomato	28.32	33.54
Pepper	18.18	21.08
Grape	30.52	26.04
Rice	35.40	37.61
Alfalfa	6.48	6.73

WHEAT - Potential yield / Potential income in North Macedonia



Source: Ece Aksoy (FAO).
Map conforms to UN world map, February 2019.
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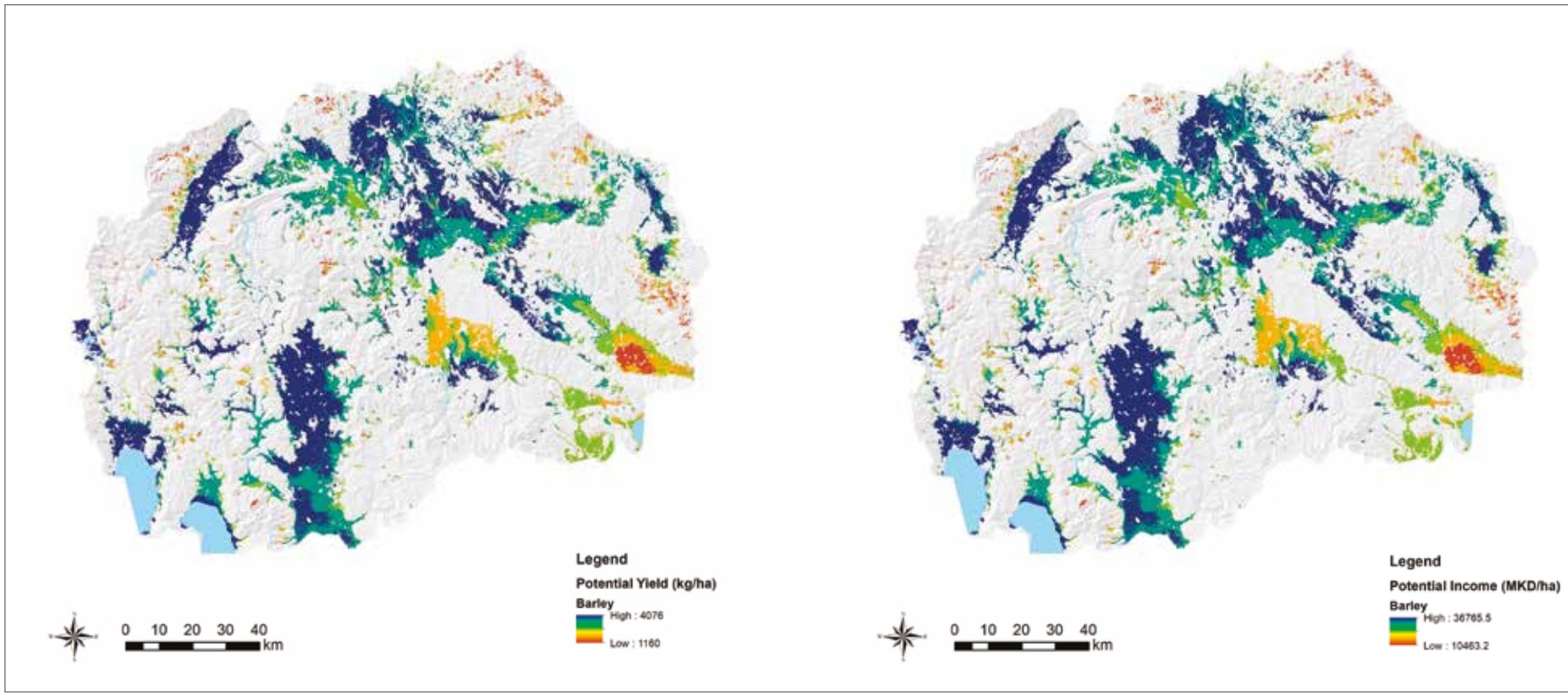
BARLEY - Potential yield / Potential income in North Macedonia



Source: Ece Aksoy (FAO).
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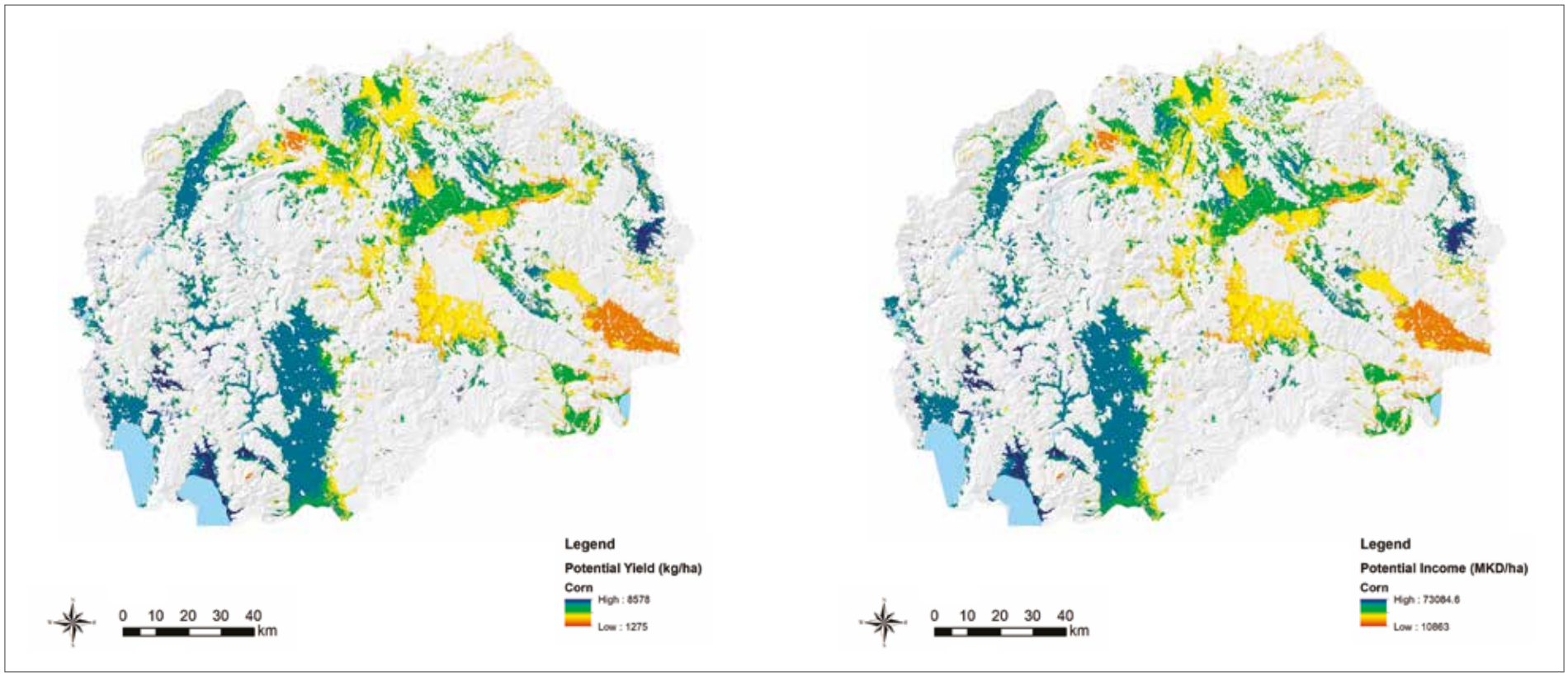
CORN - Potential yield / Potential income in North Macedonia



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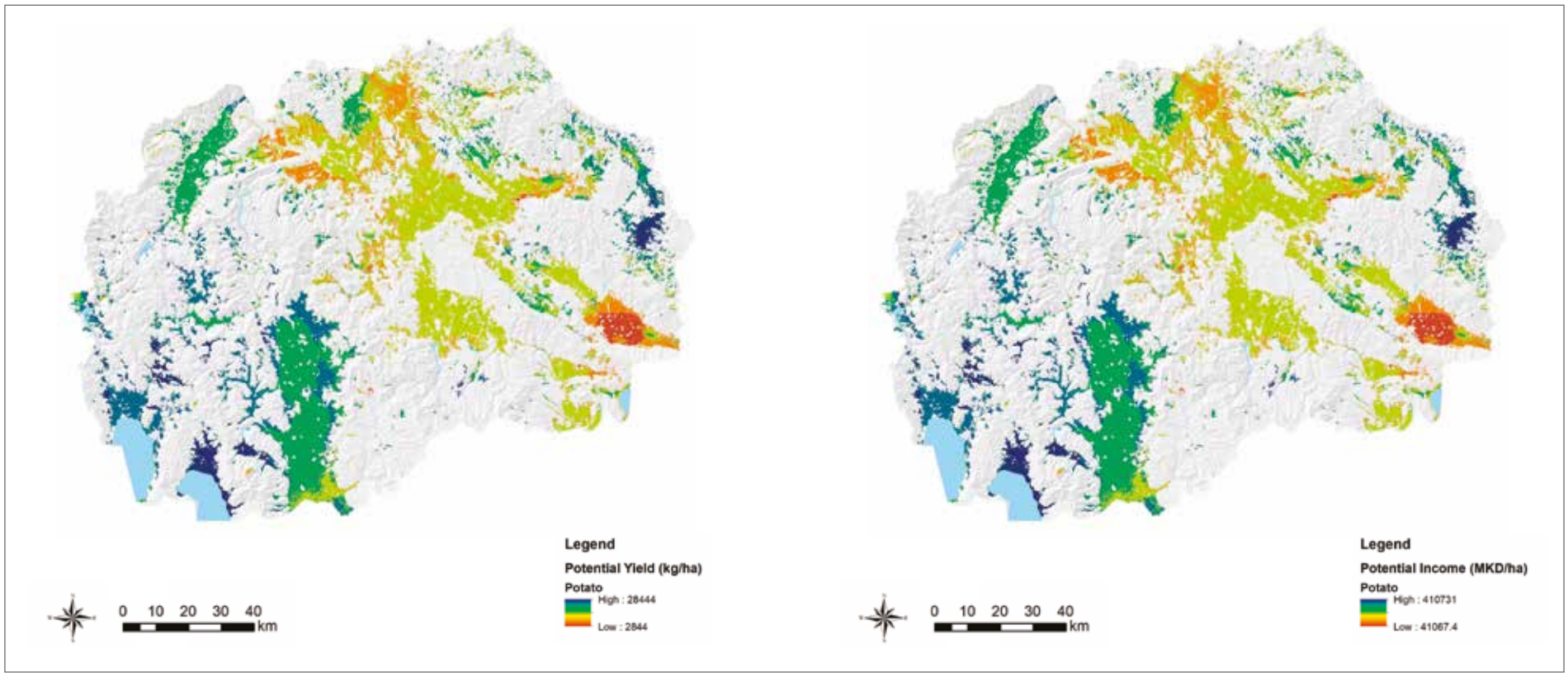
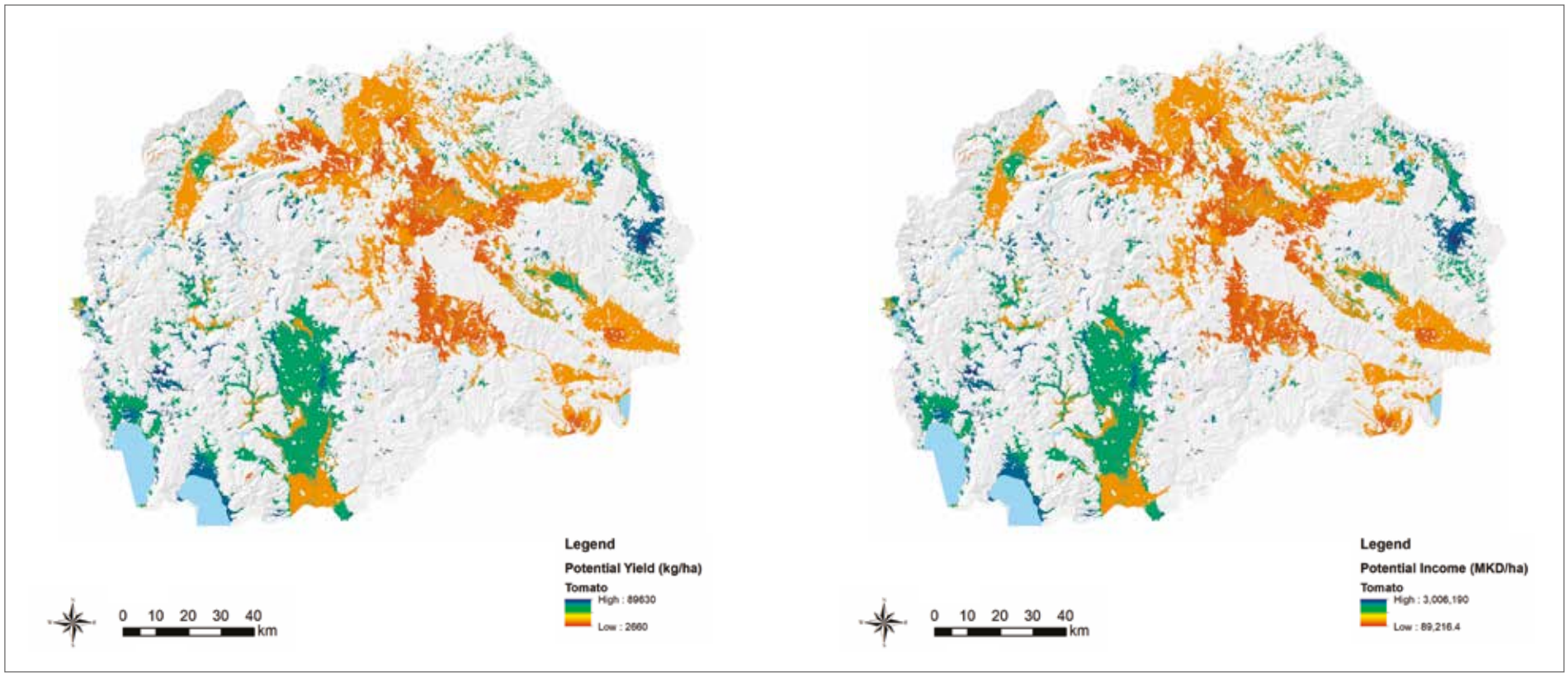
Map conforms to UN world map, February 2019.
Dashed lines on maps represent approximate border lines for which there may not yet be full agreement.

POTATO - Potential yield / Potential income in North Macedonia



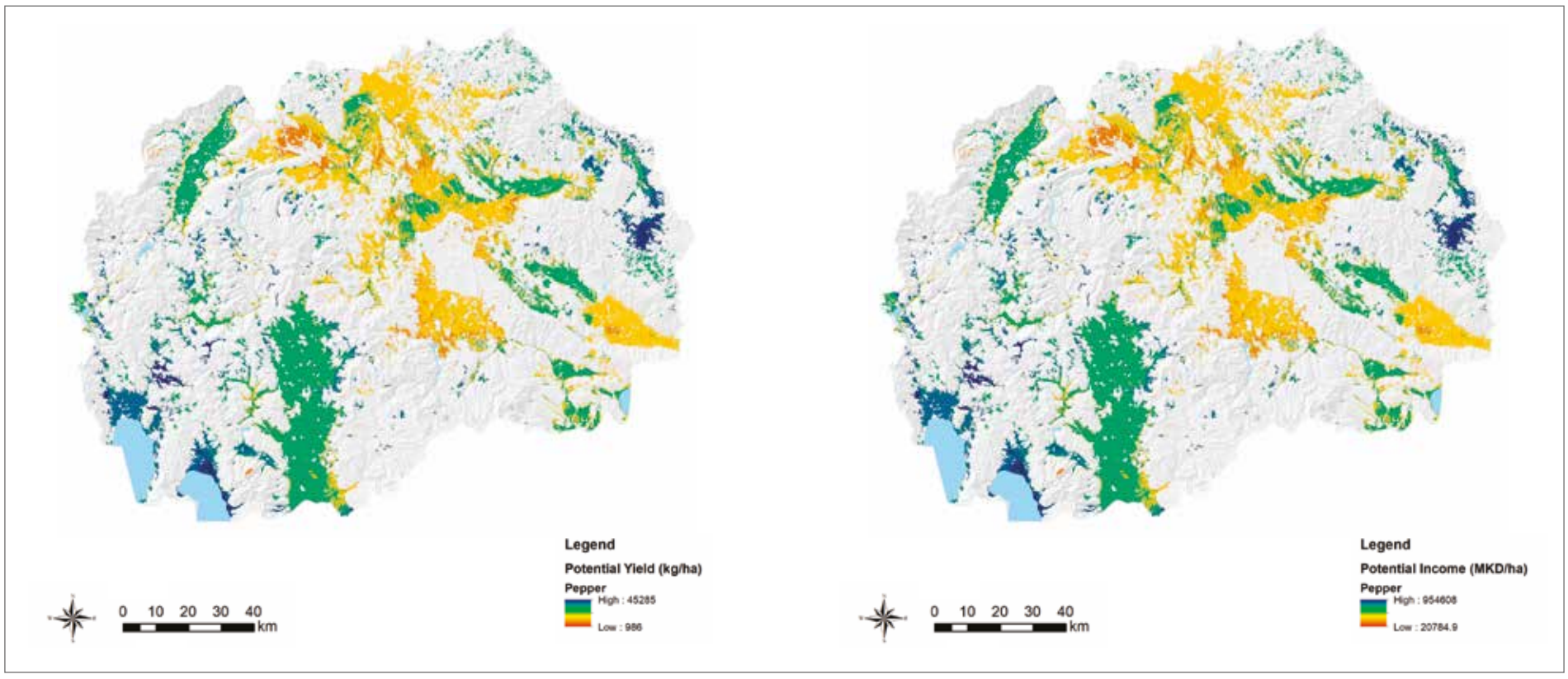
Source: Ece Aksoy (FAO).
Map conforms to UN world map, February 2019.
Dashed lines on maps represent approximate border lines for which there may not yet be full agreement.

TOMATO - Potential yield / Potential income in North Macedonia



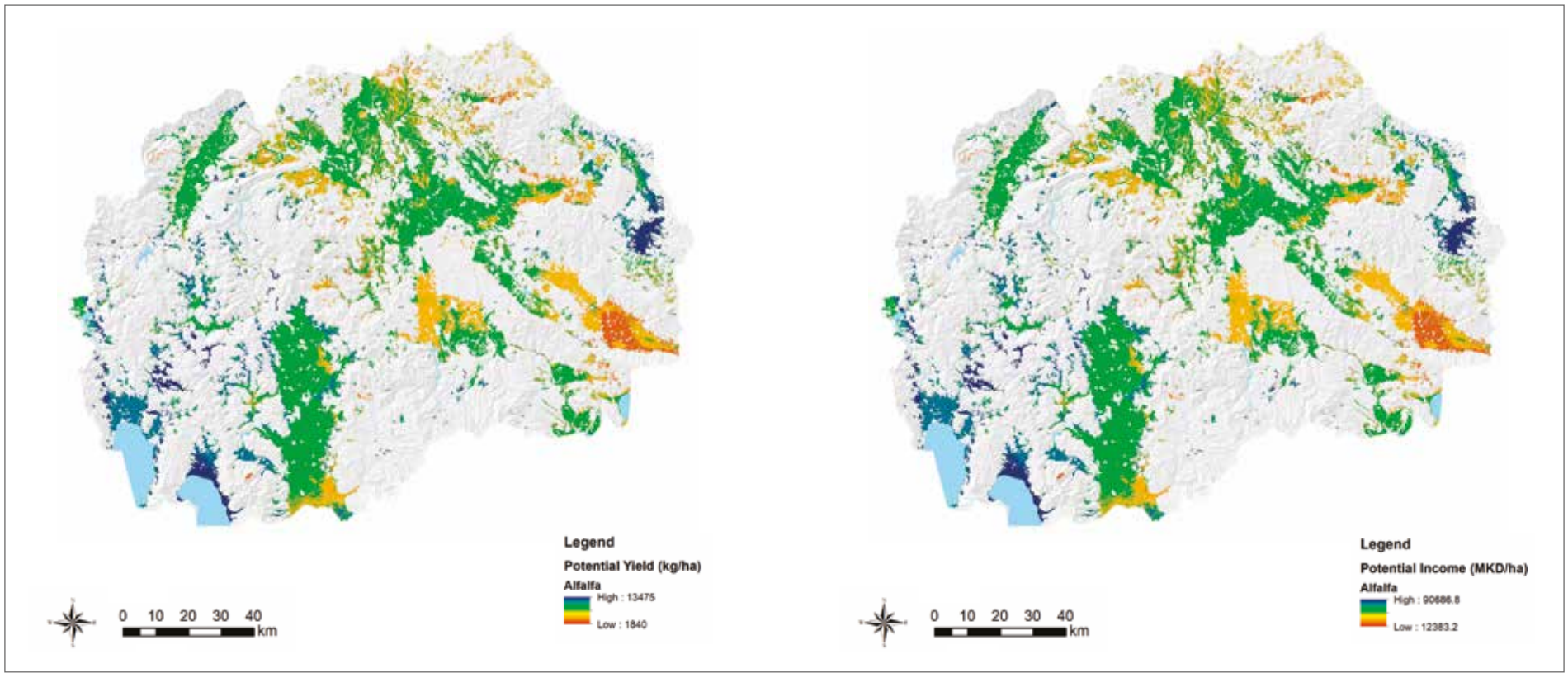
Source: Ece Aksoy (FAO).
Map conforms to UN world map, February 2019.
Dashed lines on maps represent approximate border lines for which there may not yet be full agreement.

PEPPER - Potential yield / Potential income in North Macedonia



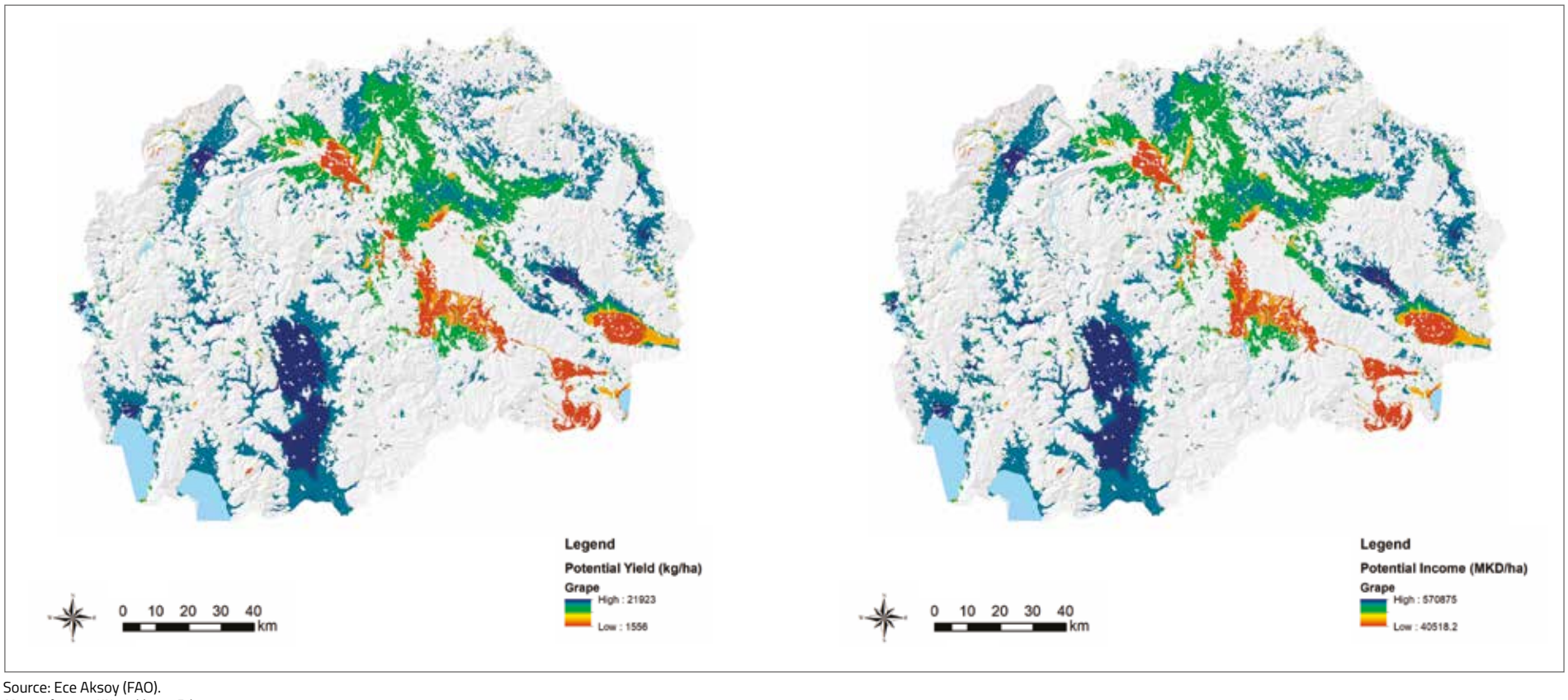
Source: Ece Aksoy (FAO).
Map conforms to UN world map, February 2019.
Dashed lines on maps represent approximate border lines for which there may not yet be full agreement.

ALFALFA - Potential yield / Potential income in North Macedonia



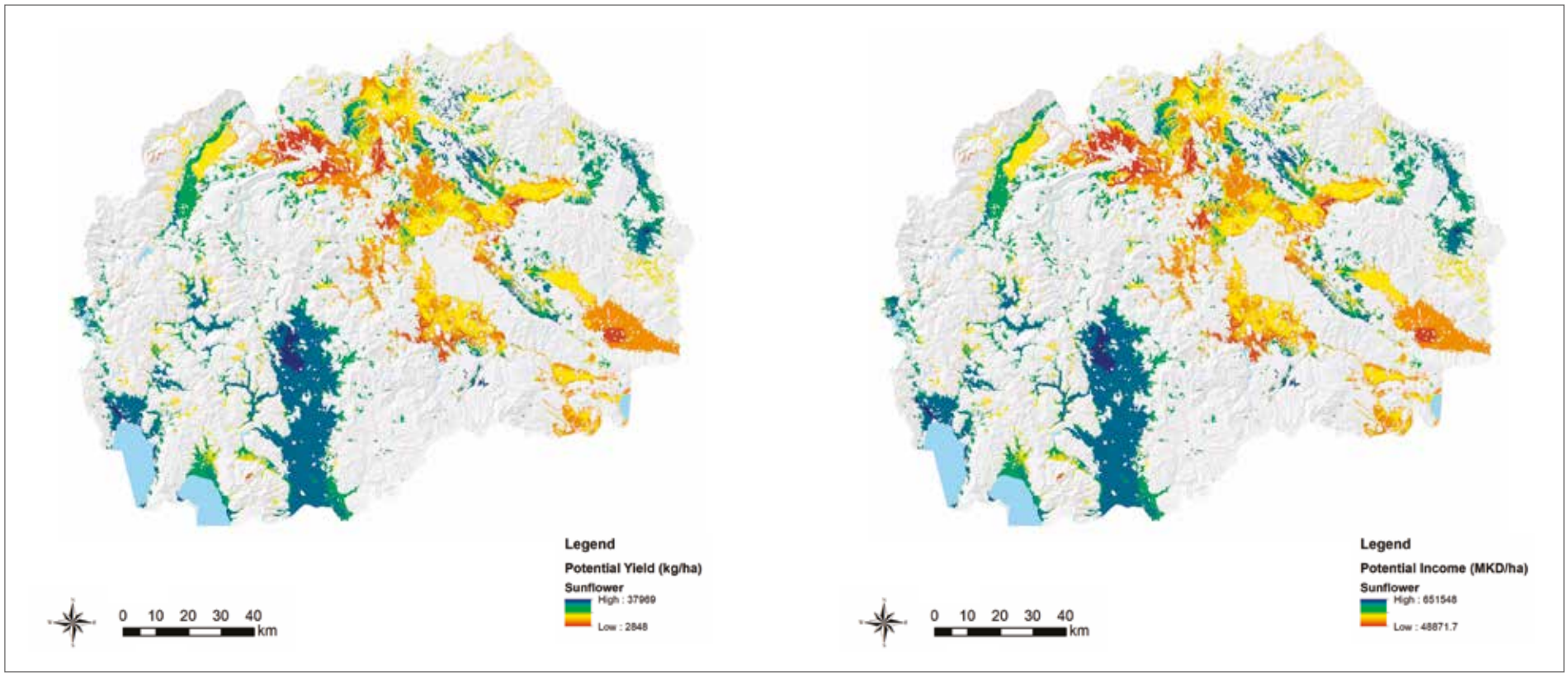
Source: Ece Aksoy (FAO).
Map conforms to UN world map, February 2019.
Dashed lines on maps represent approximate border lines for which there may not yet be full agreement.

GRAPE - Potential yield / Potential income in North Macedonia



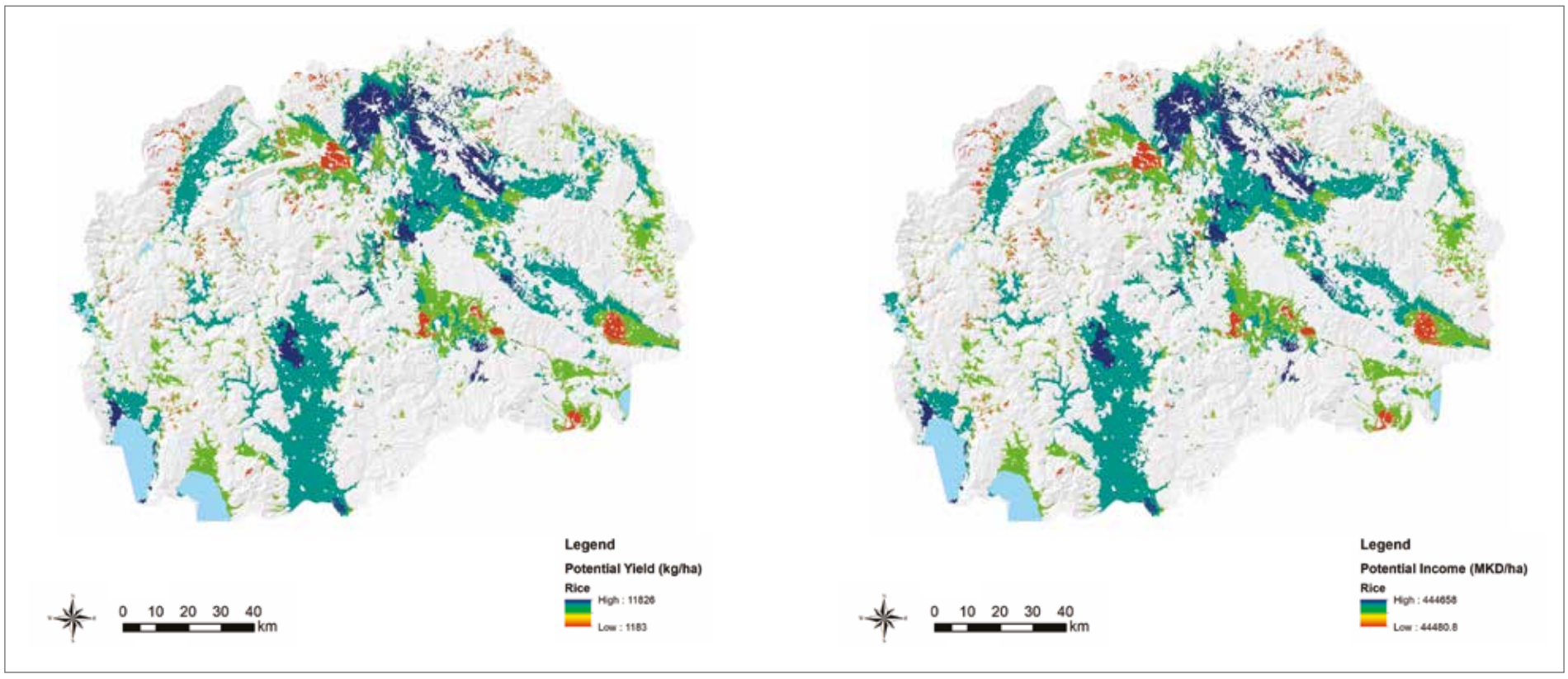
Source: Ece Aksoy (FAO).
Map conforms to UN world map, February 2019.
Dashed lines on maps represent approximate border lines for which there may not yet be full agreement.

SUNFLOWER - Potential yield / Potential income in North Macedonia



Source: Ece Aksoy (FAO).
Map conforms to UN world map, February 2019.
Dashed lines on maps represent approximate border lines for which there may not yet be full agreement.

RICE - Potential yield / Potential income in North Macedonia



Source: Ece Aksoy (FAO).
Map conforms to UN world map, February 2019.
Dashed lines on maps represent approximate border lines for which there may not yet be full agreement.

4.2 Yield gaps

In addition to the yield projections, yield gaps are calculated providing a representation on the gaps between the projected potential yield and existing yields. A useful information which provides insight into areas where there is potential for improvement of production capacities of the analyzed crops. The potential yields of the crops calculated in the previous chapter and actual yields are prepared in digital format as layers that are based on the information obtained from the statistical averages of the country data.

POTENTIAL YIELD – ACTUAL YIELD

- the exact numbers of the yield gaps are rescaled;
- one means low yield gaps, meaning that there is a small difference between the actual and potential yield;
- ten means high yield gap, meaning that the actual yield is low even though the potential yield is high which means that the yield gap between the actual and potential yield is greater.

The layers reveal the information about the locations, which we could expect to obtain much higher yields for those regions, which is indicated as high yield gaps, for example, a yield gap of ten means that a potentially ten times higher yield could be achieved based on the agro-ecological potential of the locations.

The outputs of these analyses are given in the following maps. Since we do not have the actual information per municipality for the potato and rice crops, we could not calculate the yield gaps for those crops.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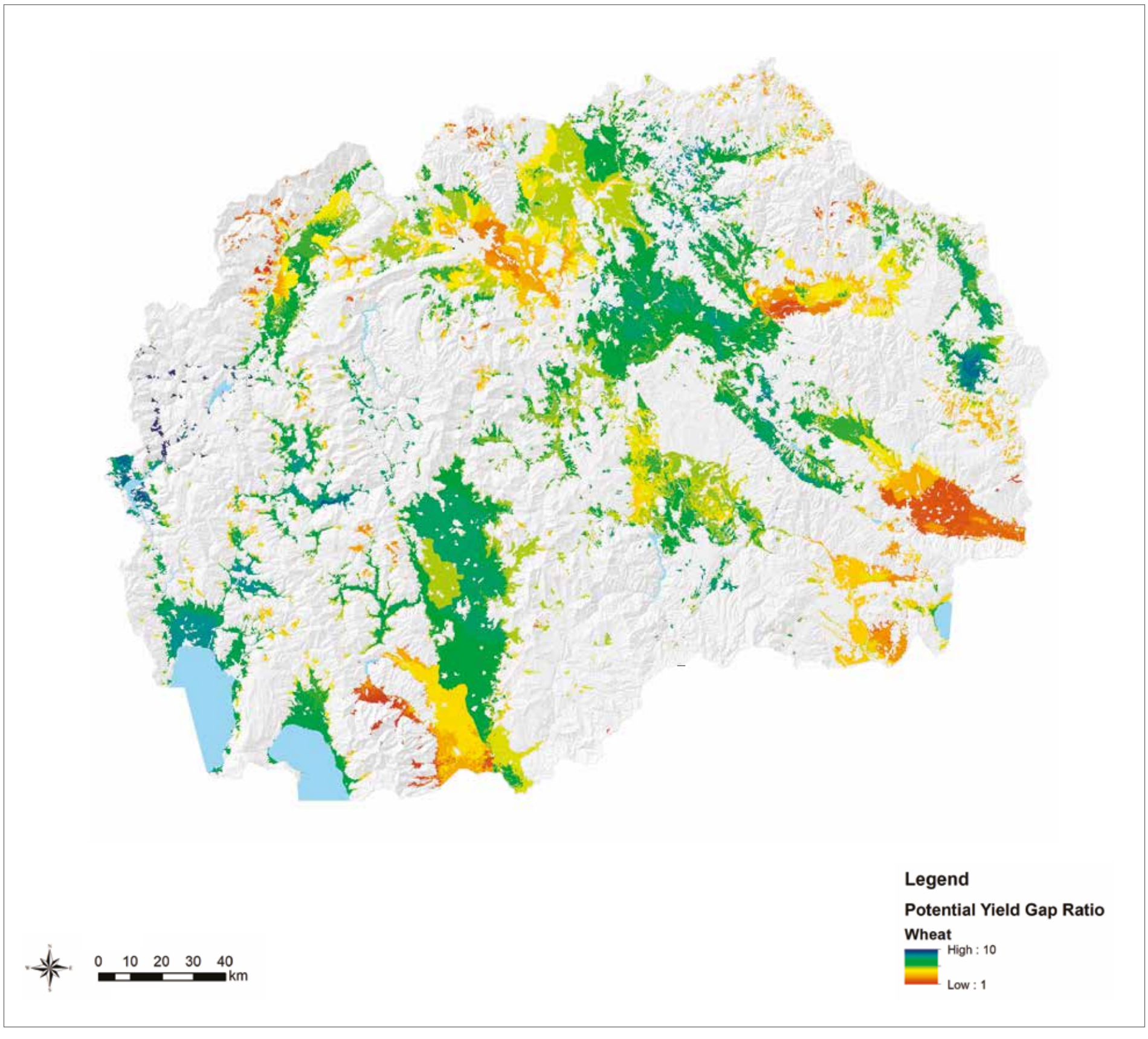
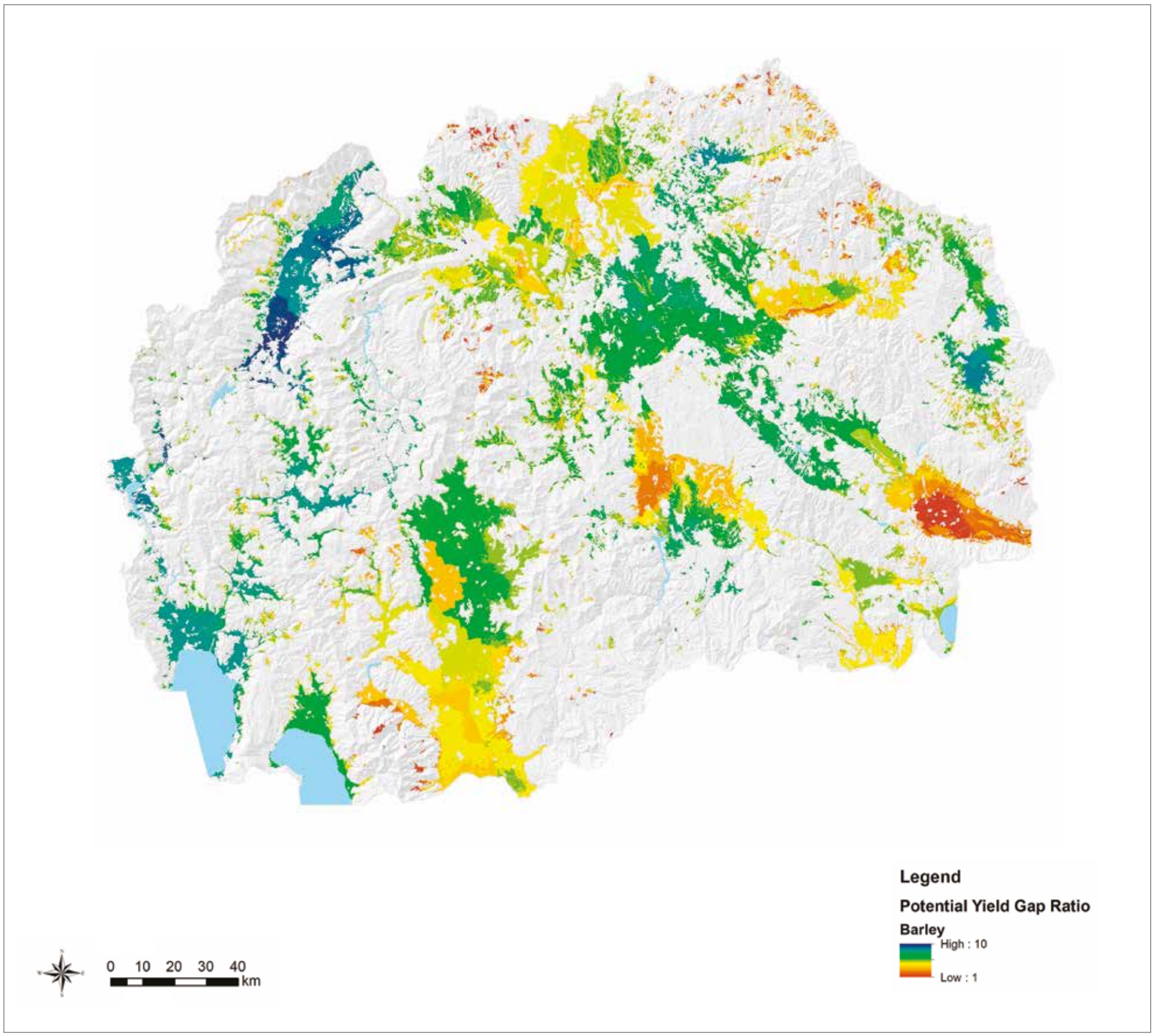
WHEAT - Potential yield gap in North Macedonia



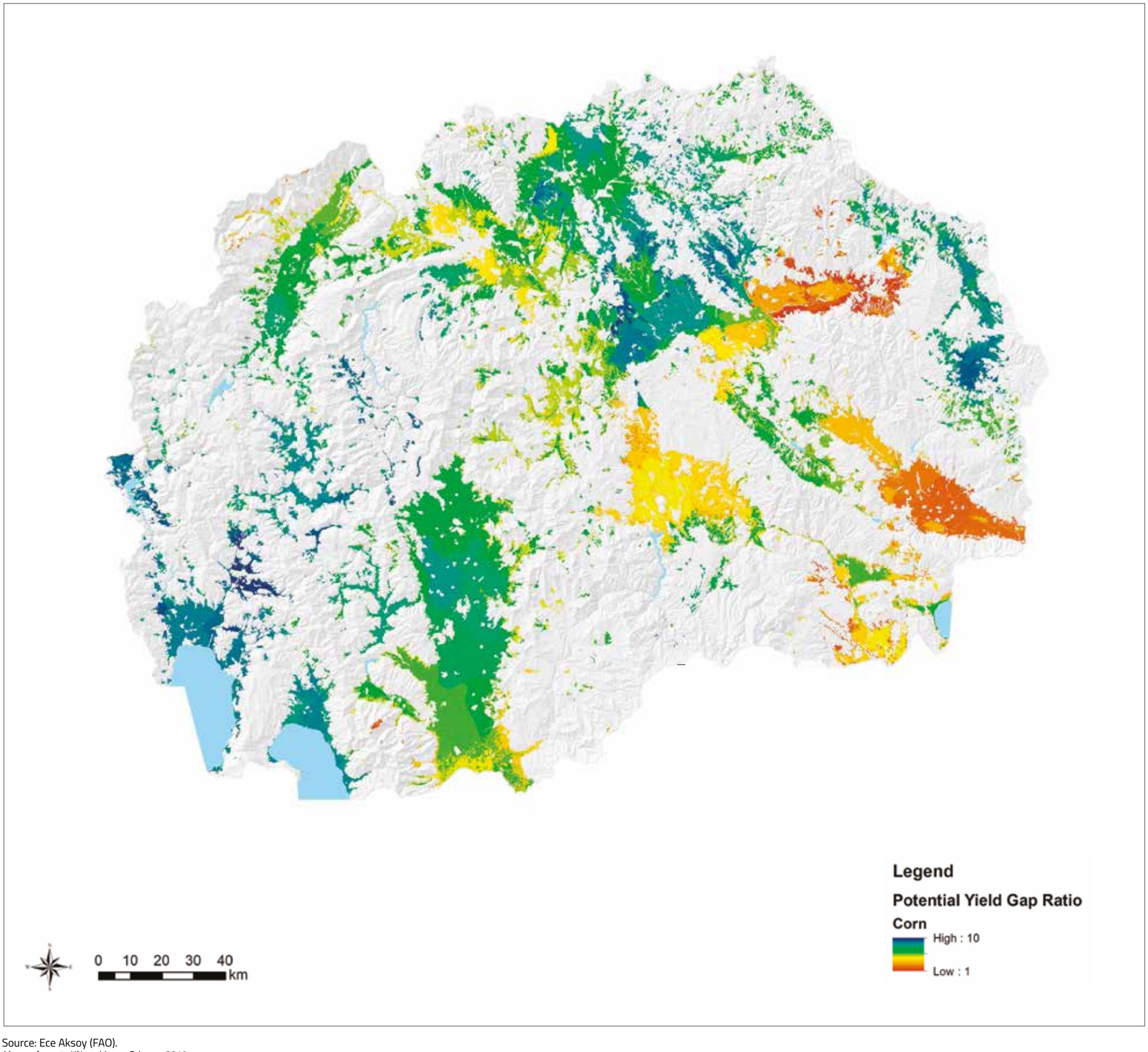
Source: Ece Aksoy (FAO).
Map conforms to UN world map, February 2019.
Dashed lines on maps represent approximate border lines for which there may not yet be full agreement.

BARLEY - Potential yield gap in North Macedonia



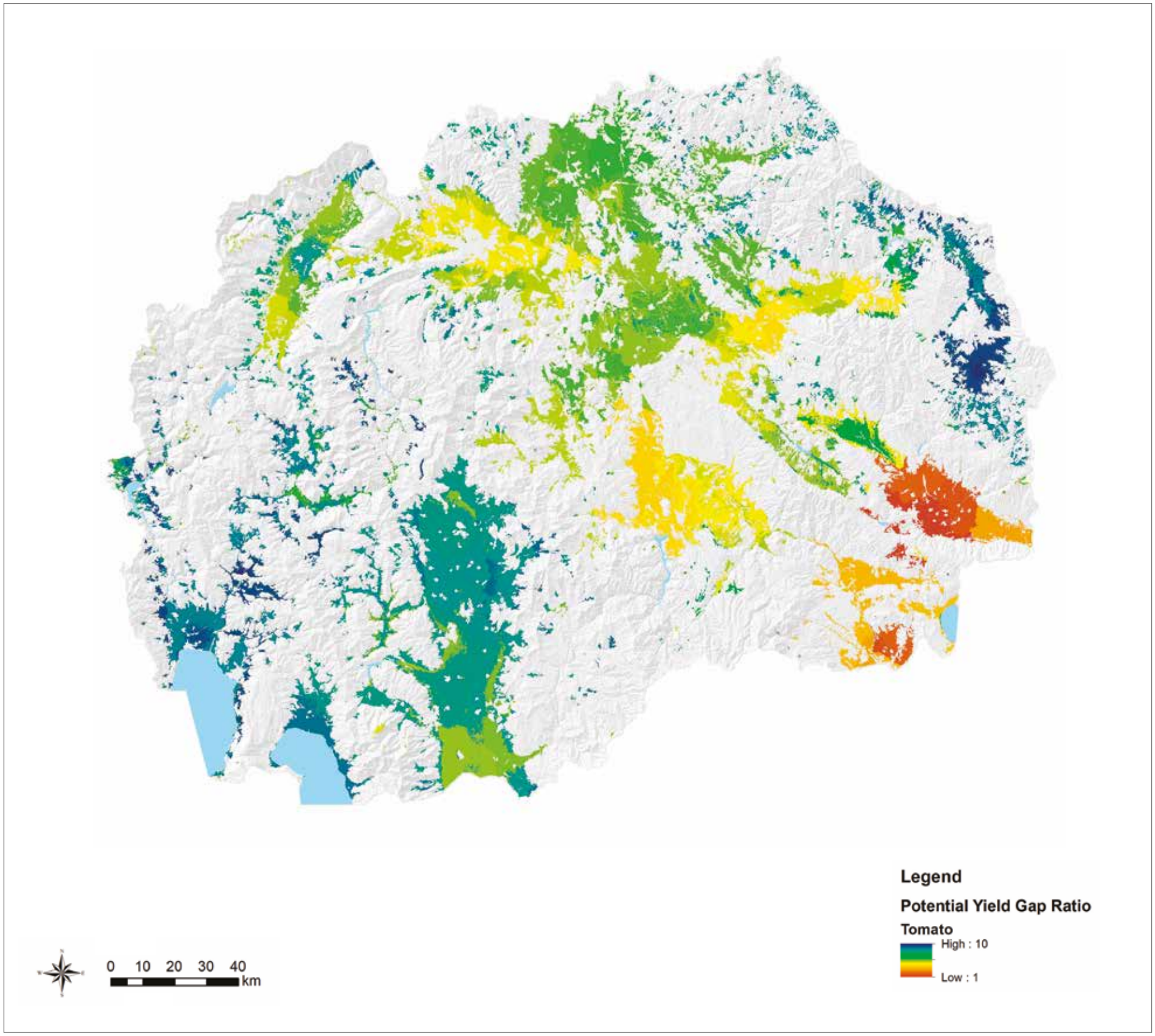
Source: Ece Aksoy (FAO).
Map conforms to UN world map, February 2019.
Dashed lines on maps represent approximate border lines for which there may not yet be full agreement.

CORN- Potential yield gap in North Macedonia



Source: Ece Aksoy (FAO).
Map conforms to UN world map, February 2019.
Dashed lines on maps represent approximate border lines for which there may not yet be full agreement.

TOMATO - Potential yield gap in North Macedonia



Source: Ece Aksoy (FAO).
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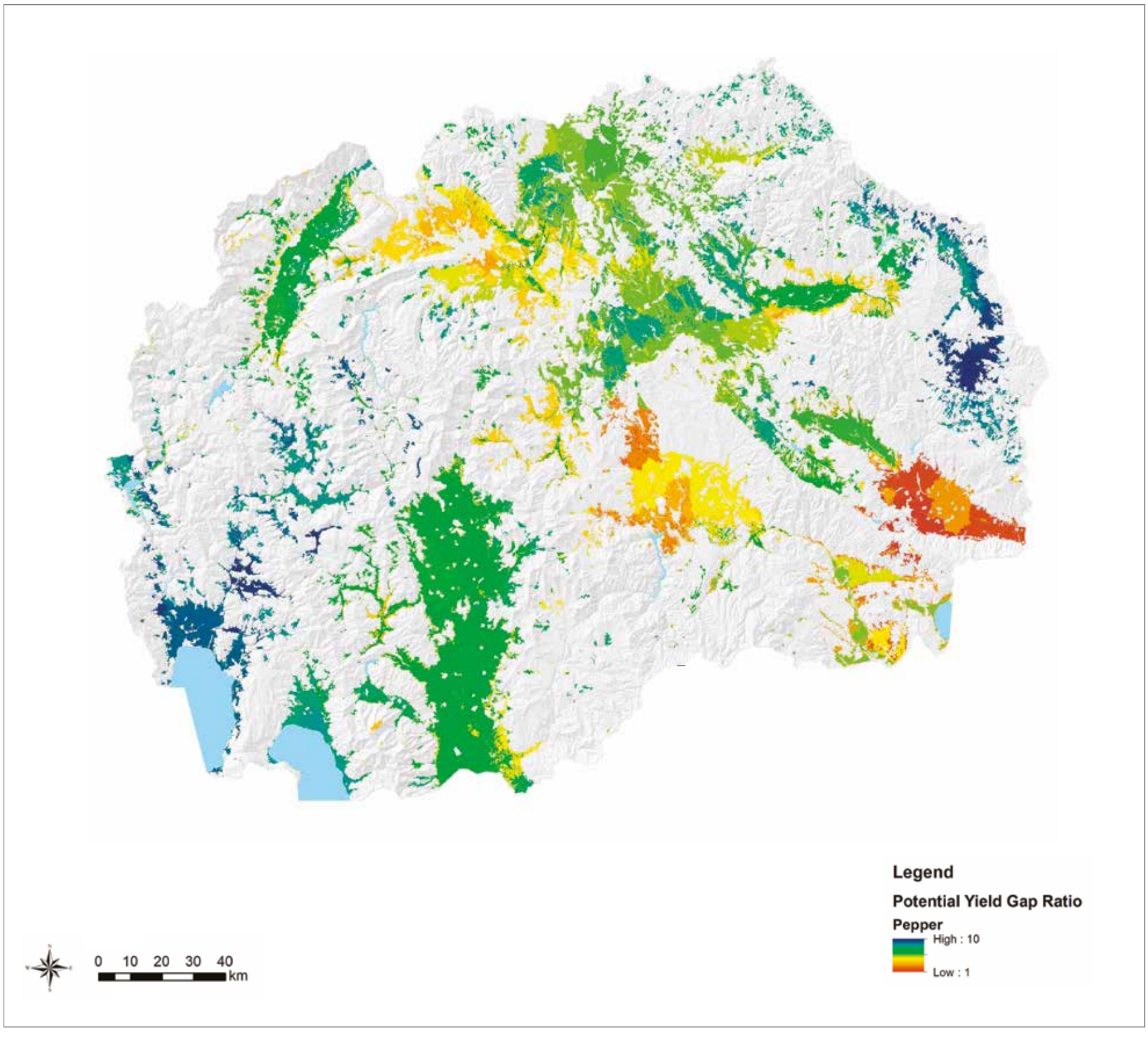
PEPPER- Potential yield gap in North Macedonia



Source: Ece Aksoy (FAO).
Map conforms to UN world map, February 2019.
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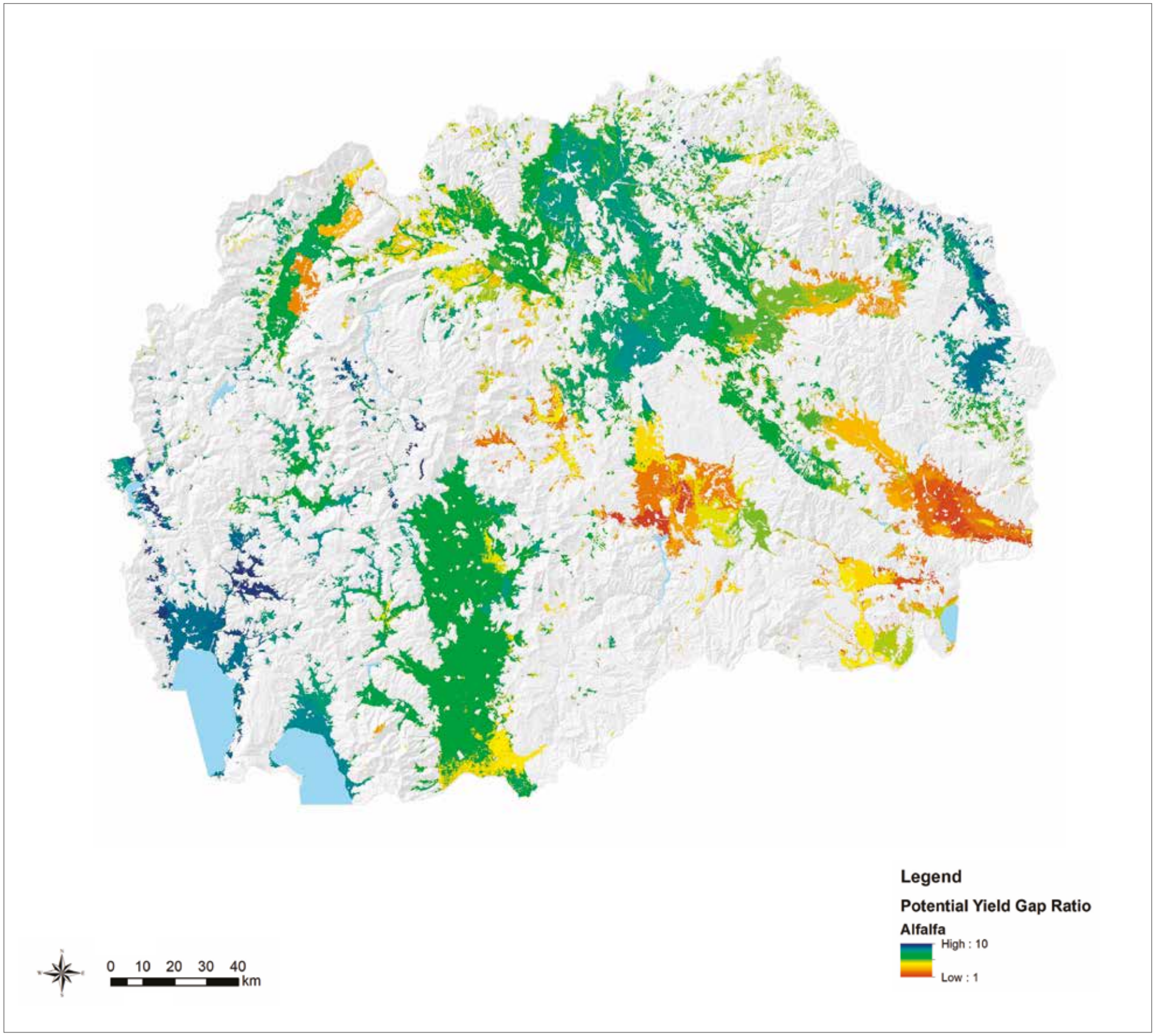
ALFALFA - Potential yield gap in North Macedonia



Source: Ece Aksoy (FAO).
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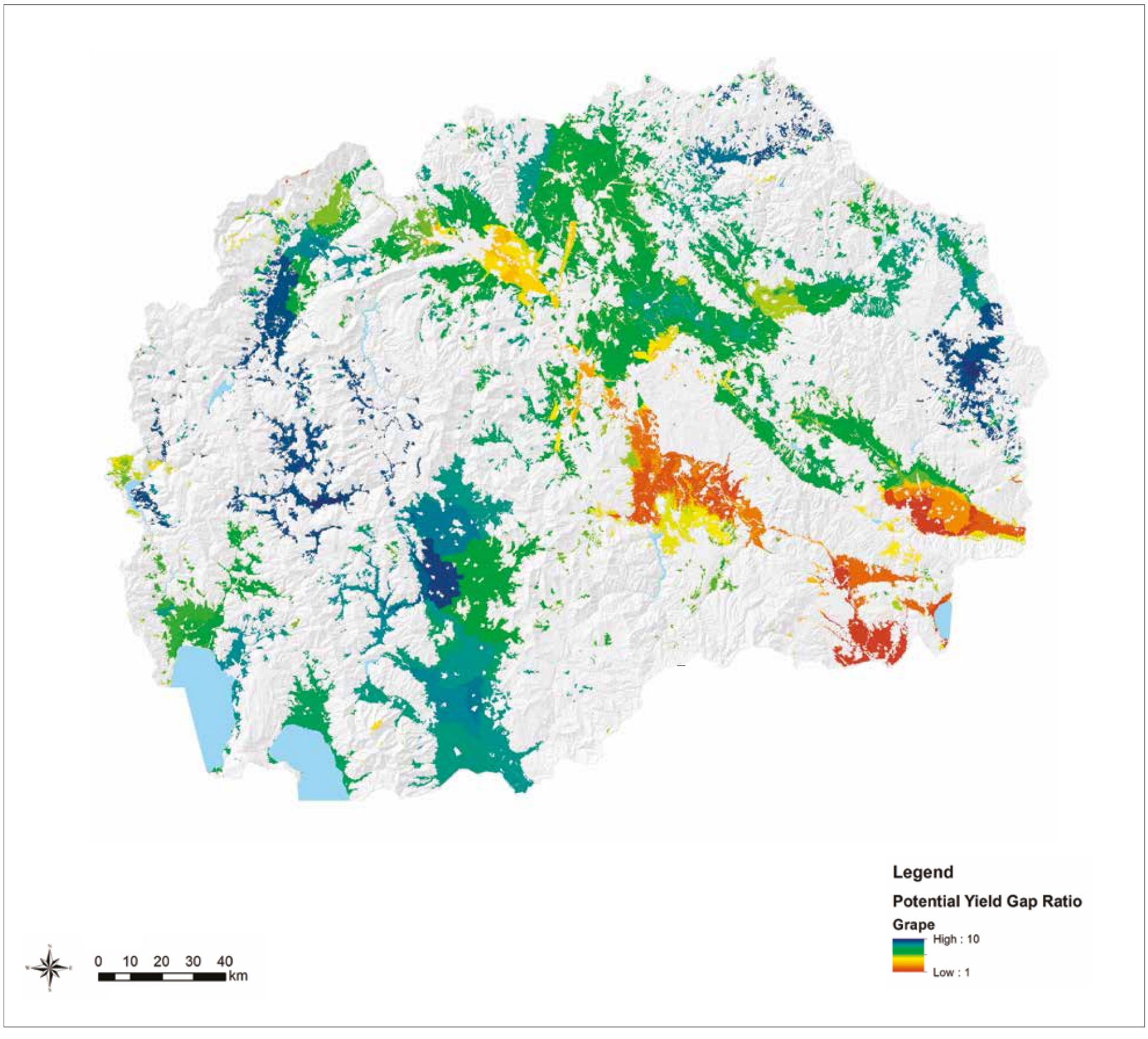
GRAPE- Potential yield gap in North Macedonia



Source: Ece Aksoy (FAO).
Map conforms to UN world map, February 2019.
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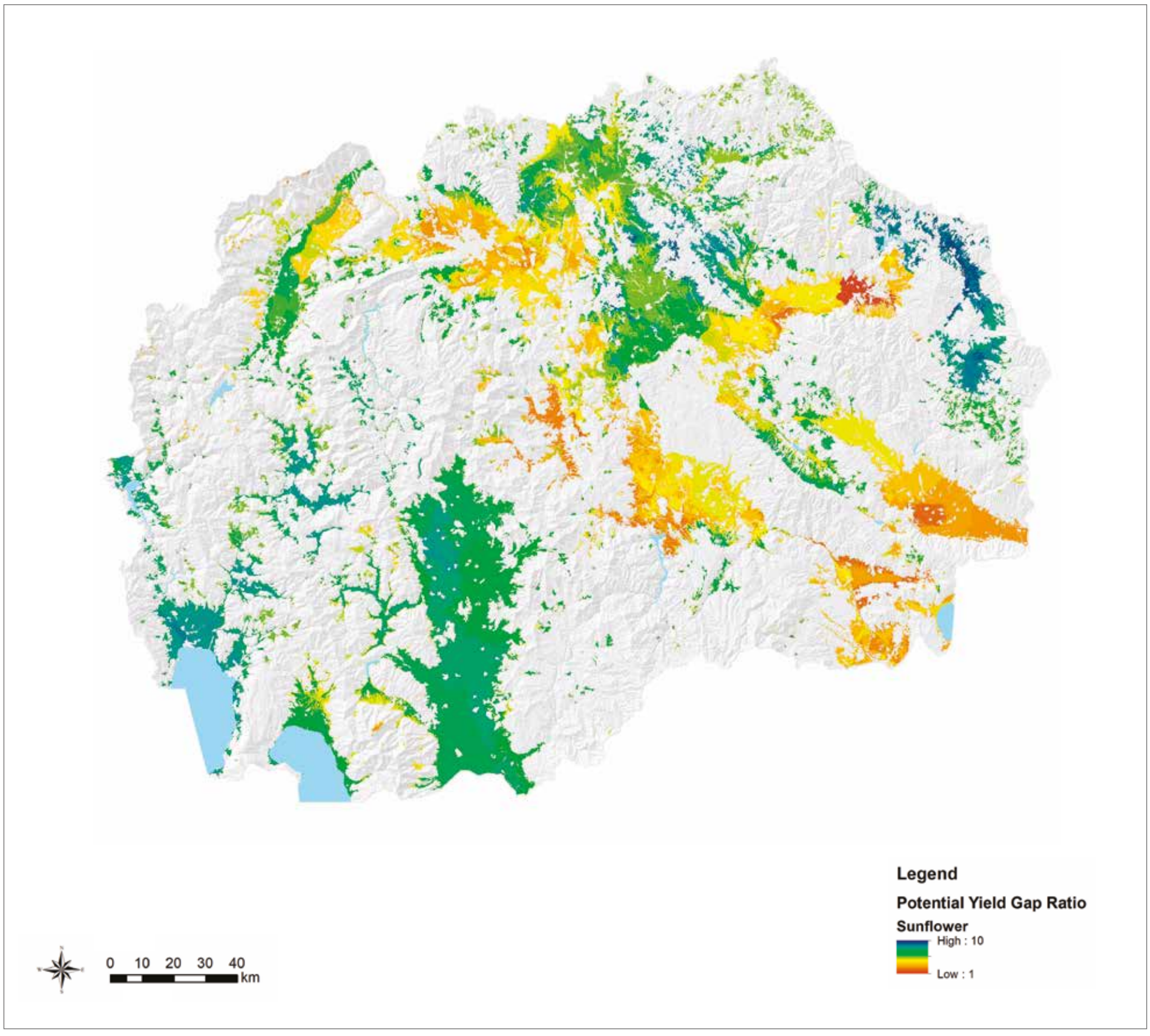
SUNFLOWER - Potential yield gap in North Macedonia



Source: Ece Aksoy (FAO).
Map conforms to UN world map, February 2019.
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Agro-ecological atlas of the Republic of North Macedonia

Corrigendum

Updated on 30 January 2020

The following corrections were made to the PDF of the report after it went to print.

Page	Location	Text in printed report	Text in corrected PDF of report
viii	Second line into the text	For this purpose, MAFWE with the support of FAO initiated activities (…)	For this purpose, MAFWE with the support of FAO's Technical Cooperation Program project TCP/MCD/3602 (Assessment of agriculture production through NAEZ and LRIMS and scenario development in the Republic of North Macedonia) initiated activities (…)

Republic of North Macedonia

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forestry and water economy**

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