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Strategic Transformation in Agriculture and Rural Space (STARS)

Pilot 2

Agricultural Spatial Land Use Planning to Support Optimize Sustainable Agriculture Management in Croatia

GUIDANCE NOTE

April 2021

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EUROPSKI POLJOPRIVREDNI FOND ZA RURALNI RAZVOJ:
EUROPA ULAŽE U RURALNA PODRUČJA MJERA TEHNIČKA POMOĆ

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Agricultural Spatial Land Use Planning to Support Optimize Sustainable Agriculture Management in Croatia

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The report was prepared by a World Bank Group technical team of staff and consultants led by Svetlana Edmeades and comprising Erika Felix (main author), Gabriel Origel-Gutierrez and Jela Bilandzija. The team is very grateful to Ece Aksoy, Tomislav Hengl (at EnvirometriX), Josip Križan (at MultiOne) and Matko Mesic for their technical inputs to this work. The Team acknowledges the guidance provided by the Croatian agencies participating in the technical working group organized for the purposes of this work and the support of the Ministry of Agriculture for the preparation of this report. The team is also grateful to the support provided by Elisabetta Capannelli (Country Manager, Croatia) and Frauke Jungbluth (Practice Manager, Agriculture and Food Global Practice) and to comments received by Austin Kilroy, Jan Nijhoff and Luka Bacic.

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Abbreviations

ACZ	Agro-climatic Zonification
AEZ	Agro-ecological Zonification
AHP	Analytical Hierarchy Process
BD	Biodiversity Strategy
CAP	Common Agricultural Policy
DHMZ	Croatian Meteorological and Hydrological Service
EC	European Commission
EEA	European Economic Area
EGD	European Green Deal
EO	Earth Observation
FtF	Farm to Fork
GSW	Global Surface Water
HAPIH	Croatian Agency for Agriculture and Food
HBOR	Croatian Bank for Reconstruction and Development
HEAL	Helping Enterprises to Access Liquidity
JRC	Joint Research Centre
LGP	Length of Growing Period
LUT	Land Utilization Type
MESD	Ministry of Economy and Sustainable Development
MoA	Ministry of Agriculture
NAEZ	National Agro-Ecological Zonification
NARDS	National Agricultural and Rural Development Strategy
NIPP	National Spatial Data Infrastructure
NRRP	National Recovery and Resilience Plan
SSM	Surface Soil Moisture
TWG	Technical Working Group
UNFCCC	United Nations Climate Change Convention
WRB	World Reference Base

1 Introduction

Business as usual is not an option; the agricultural sector must undergo a transformation to achieve higher sustainability objectives. In 2018, the European Commission adopted a legislative proposal for a "new" simplified and modernized Common Agricultural Policy (CAP) for the period 2021-2027 paving the way for a more environmentally, economically, and socially sustainable programming in one of the most important sectors. In December 2019, the Commission further announced its commitment to sustainability through the European Green Deal (EGD), a new growth strategy that aims to transform the EU into a fair and prosperous society, with a modern, resource-efficient, and competitive economy where there are no net emissions of greenhouse gases in 2050 and where economic growth is decoupled from resource use.[1] These ambitions are particularly binding for the agri-food sector given its strong links to nature and climate change. Several recent reports indicate that the greening of the 2014-2020 CAP programing period was not sufficient to reverse biodiversity decline (EC, 2020[2]). The EGD calls for a paradigm shift away from industrial farming and towards sustainable production of food coupled with preservation of ecosystems and biodiversity. Table 1 summarizes the key agriculture related targets under the EGD and the associated CAP regula-

1 European Commission (2021). The European Green Deal. Available online: https://ec.europa.eu/info/sites/info/files/european-green-deal-communication_en.pdf (accessed on January 19, 2021).

2 European Commission (2021). Analysis of links between CAP Reform and Green Deal, Commission Staff Working Document, SWD (2020) 93 final, Brussels.

tions.[3] The Commission expects that the ambition of the EDG and its Farm to Fork and Biodiversity Strategies (captured in the proposed targets) is fully reflected in future national CAP Strategic Plans. The Commission has signaled that a robust climate and environmental criteria will be used to assess these Plans ex-ante and evaluate their performance ex-post.

Sustainability is gaining importance in the development agenda of Croatia. The National Agricultural and Rural Development Strategy (NARDS) recognizes that Croatia has a significant opportunity to improve current agricultural productivity with climate-smart and sustainable practices and technologies. It also identifies the management of the country's rich agricultural biodiversity, including genetic resources as a value-addition opportunity linked to sustainable higher value market segments, while increasing the climate resilience of producers by helping plants and animals adapt to climate change, preserving ecosystem health, and improving soil fertility and water quality. Furthermore, the Government Program of Croatia recognizes spatial planning policies are needed to manage in a planned, responsible, and rational manner its resources. To address this, the formulation of a Physical Planning Information System at the national, regional, and local level is proposed. In addition, the Government commits to have a National Spatial Data Infrastructure (NIPP), where spatial plans will be integrated with other spatial information to enable digital public use.

Putting agriculture on a more sustainable path will be a requirement, but also an opportunity. Agricultural intensification has led to a strong homogenization of agricultural landscapes and loss of natural and semi-natural habitats and the biodiversity that depends on

TABLE 1. Potential indicators in Annex I of the proposed CAP Strategic Plan Regulation associated with EGD targets[4]

European Green Deal targets related to the agricultural sector	Impact indicators[5]	Output and result indicators[6]
• Reducing by 50% the use and the risk of chemical pesticides by 2030 • Reducing by 50% the use of high-risk pesticides	**I.27** Sustainable use of pesticides: reduce risks and impacts of pesticides	**R.37** Sustainable pesticide use: share of agricultural land concerned by supported specific actions which lead to a sustainable use of pesticides
• Reducing by 50% the sales of antimicrobials for farmed animals and in aquaculture by 2030	**I.26** Limiting antibiotic use in agriculture: sales/use in food producing animals	**R.36** Limiting antibiotic use: share of livestock units concerned by supported actions to limit use of antibiotics
• Reducing nutrient losses by at least 50% in 2030 without deterioration in soil fertility • Reduce 20% the use of fertilizers	**I.15** Improving water quality: Gross nutrient balance on agricultural land	**R.21** Sustainable nutrient management: share of agricultural land under commitments related to improved nutrient management
• Achieve 25% agricultural area under organic farming by 2030	**C.32** Agricultural area under organic farming	**O.15** Number of ha with support for organic farming
• Completing fast broadband internet access in rural areas reach		**R.34** Connecting rural Europe: share of rural population benefiting from improved access to services and infrastructure through CAP support
• Bring back at least 10% of the agricultural area under high-diversity landscape features for biodiversity	**I.20** Enhanced provision of ecosystem services: share of UAA covered with landscape features	**R.29** Preserving landscape features: share of agriculture land under commitments for managing landscape features, including hedgerows

3 https://ec.europa.eu/info/sites/info/files/food-farming-fisheries/sustainability_and_natural_resources/documents/analysis-of-links-between-cap-and-green-deal_en.pdf

4 The indicators are still under negotiation and evolving as discussions among key parties ae still ongoing.

5 As laid down in Annex I or Context Indicators as envisaged in secondary legislation.

6 As laid down in Annex I.

them (Foley et al. 2005[7]). In the EU, it is estimated that only 23% of species and 16% of habitats under the EU Nature Directives are in good health. The number and variety of species on farmland have declined at a particularly rapid rate (EEA, 2020[8]). EU farmers widely use chemical fertilizers to optimize production, with an estimated 10.2 million tons of nitrogen fertilizer and 1.1 million tons of phosphorus used in 2019.[9] In May 2020, the EU published the Biodiversity Strategy and the Farm to Fork Strategy (FtF) as a part of the policy actions under the EGD. The Biodiversity Strategy proposes a transformative and holistic approach to tackle the biodiversity crisis by protecting and restoring nature, addressing the main drivers of biodiversity loss and enabling transformative change. The FtF Strategy addresses the agri-food supply chain in an integrated way, from primary production of animal and plant foods to consumer food choices and food waste, to identify a more sustainable path of the European food system. The European Commission suggests that Member Countries be prepared to identify and proactively consider these objectives in their national CAP agricultural planning processes. To that end the Commission published in December 2020 a set of specific recommendations to each Member state as guidance to their CAP strategic plans, paying particular attention to addressing the EGD targets, as well as those stemming from the FtF and Biodiversity strategies. In the case of biodiversity, enhancing direct payments for environmental public goods, better targeting biodiversity conservation under the rural development program, and conserving agricultural genetic diversity are some of the opportunities.[10] Likewise, the ambitions of the FtF Strategy are closely linked to CAP support for organic farming and more efficient nutrient management (fertilizer and pesticide) support.

Reversing soil degradation and biodiversity loss are smart management choices. Soil is important for agricultural production and is also important to biodiversity as it is holds 25% of all biodiversity in the earth.[11] In 2016 an estimated 11.6 % of Europe's land area is affected by moderate to severe water erosion.[12] In 2010 an estimated 32-36% of European subsoils had high or very high susceptibility to compaction and 45% of the mineral soils in Europe had low or very low organic carbon content.[13] Environmental problems occur when land is not used in accordance with its physical properties. Better understanding of environmental and soil degradation can support policy decision-making by introducing gradual pro-active changes into the agricultural system that will encourage farmers to take up more productive and sustainable forms of land use. Land suitability analysis can support this process by identifying the optimal land use options. The analysis can help reconcile multiple objectives to help define sustainable food production systems, identify areas where protection and co-existence of agricultural production and biodiversity and ecosystems services can be pursued.

Climate action is at the heart of the EGD and is of high relevance to agriculture. Agriculture accounts for around 10% of total GHG emissions in Croatia, which are largely associated with livestock farming (enteric fermentation). Agriculture is highly vulnerable to climate change, as farming activities are directly affected by climate. Hence agriculture is a priority sector for adaptation in the country. Weather extremes are becoming more frequent with more recurrent and longer drought periods posing a major threat to agricultural areas. Between 2000 and 2007 alone the annual economic losses to agriculture in Croatia from extreme weather events were estimated at around €173 mil-

7 Foley JA, et al. (2005). Global consequences of land use. Science 309, 570–574.

8 https://www.eca.europa.eu/Lists/ECADocuments/SR20_13/SR_Biodiversity_on_farmland_EN.pdf

9 https://ec.europa.eu/eurostat/statistics-explained/index.php/Agri-environmental_indicator_-_mineral_fertiliser_consumption#Analysis_at_EU_level

10 https://ec.europa.eu/environment/archives/business/assets/pdf/resources-center/Agriculture%20and%20the%20EU%20Biodiversity%20Strategy.pdf

11 The factory of life: Why soil biodiversity is so important. EU. https://ec.europa.eu/environment/archives/soil/pdf/soil_biodiversity_brochure_en.pdf.

12 Panagos, P.; Ballabio, C.; Poesen, J.; Lugato, E.; Scarpa, S.; Montanarella, L.; Borrelli, P. (2020). A Soil Erosion Indicator for Supporting Agricultural, Environmental and Climate Policies in the European Union. Remote Sens. 12, 1365.

13 https://www.eea.europa.eu/soer/2010/europe/soil/key-facts

lion.[14] Without appropriate mitigation actions, these could result in even greater losses in the coming years. Agriculture can also play an important contribution to climate change mitigation by reducing greenhouse gas emissions (methane from livestock related activities and nitrous oxide from organic and mineral fertilizers) and by sequestering carbon while maintaining a sustainable food production in Croatia.

Croatia is one of the most biodiversity-rich countries in Europe and environmental objectives are very relevant. The Croatian Natura 2000 network is the second largest in the EU covering 36.5% of Croatian land area and roughly one third of the network is linked to agricultural land. The overall status and protection of natural resources in Croatia is good. However, pressures from land consolidation and agricultural production intensification threaten the extensive cropland and agricultural mosaics which support biodiversity ecosystems. The area under organic production has more than doubled from 2013 to 2019 and is now slightly below the EU average. However, soil erosion continues to be a challenge. Croatia has an average soil loss rate by water of 3.16 tons per hectare per year compared to the EU mean of 2.46 tons.[15] Organic matter in the soil is low in the most productive areas of the country (eastern Croatia average of 2.3% SOM) compared with other European Countries (i.e. Austria and Poland with 6-12%).[16]

Croatia is moving in the direction of sustainable food production systems. Croatia reported the largest decrease (42%) of nitrogen fertilizer consumption between 2008 and 2018 despite a 2% increase at the EU level. Phosphorus consumption in Croatia also decreased by 27% during the same period, also larger than the 1% reduction at EU level.[17] The downward trend in pesticide use is also higher than at the EU level. A sustained increase in organic production along with the effective agricultural management practices are paramount to maintain and strengthen ecosystems services and build resilience. Beyond contributing to biodiversity and environmental objectives, these actions will also promote the shift to a sustainable agricultural production system.

Strategic spatial planning and management are essential for aligning land use with environmental factors and promoting climate resilient agricultural landscapes. Agroclimatic information is key to identify shift patterns in land suitability and agricultural production systems driven by future climate change. Identifying the impacts of climate variability to agricultural production is paramount for designing appropriate adaptation strategies. Land suitability combined with agroclimatic analysis can help design appropriate strategies, roadmaps, partnerships, financing mechanisms, and behavioral change programs to facilitate the development of more sustainable agricultural practices. Reducing agricultural yield gap through intensification is often promoted as an effective strategy to minimize biodiversity impacts (Cunningham et al., 2013[18]). However, land intensification may also be a threat to biodiversity in agricultural landscapes (Zabel et al. 2019[19], Egli et al. (2018[20]) demonstrated a spatial assessment integrating agricultural and biodiversity factors to optimize land use where highest production gains could be achieved at the lowest potential cost to biodiversity. As such, policymakers need updated information on land characteristics such as soil quality, topography, weather, and agricultural land use to support the planning for sustainable agricultural production.

14 http://www.seeclimateforum.org/upload/document/cva_croatia_-_english_final_print2.pdf.

15 Panagos, P. et. al. (2015). The new assessment of soil loss by water erosion in Europe. Environmental Science and Policy. Vol. 54 pp 438-447. https://www.sciencedirect.com/science/article/pii/S1462901115300654#tbl0005

16 Bogunovic, I. et. al. (2018). Mapping soil organic matter in the Baranja region: geological and anthropic forcing parameters; Aksoy E, Yigini Y, Montanarella L (2016) Combining Soil Databases for Topsoil Organic Carbon Mapping in Europe. PLoS ONE 11(3); https://www.eea.europa.eu/data-and-maps/figures/variations-in-topsoil-organic-carbon/so102-map2.1-eps-file/image_large

17 Eurostat (2018). Agri-environmental indicators mineral fertilizer consumption.

18 S. A. Cunningham, S. J. Attwood, K. S. Bawa, T. G. Benton, L. M. Broadhurst, R.K. Didham, S. McIntyre, I. Perfecto, M. J. Samways, T. Tscharntke, J. Vandermeer, M. Villard, A. G. Young, D. B. Lindenmayer (2013). To close the yield-gap while saving biodiversity will require multiple locally relevant strategies, Agriculture, Ecosystems & Environment, Volume 173, pp 20-27.

19 Zabel, F., Delzeit, R., Schneider, J. et al. (2019). Global impacts of future cropland expansion and intensification on agricultural markets and biodiversity. Nat Commun 10, 2844.

20 Egli, L., Meyer, C., Scherber, C., Kreft, H. & Tscharntke, T. (2018). Winners and losers of national and global efforts to reconcile agricultural intensification and biodiversity conservation. Glob. Change Biol. 24, pp 2212–2228.

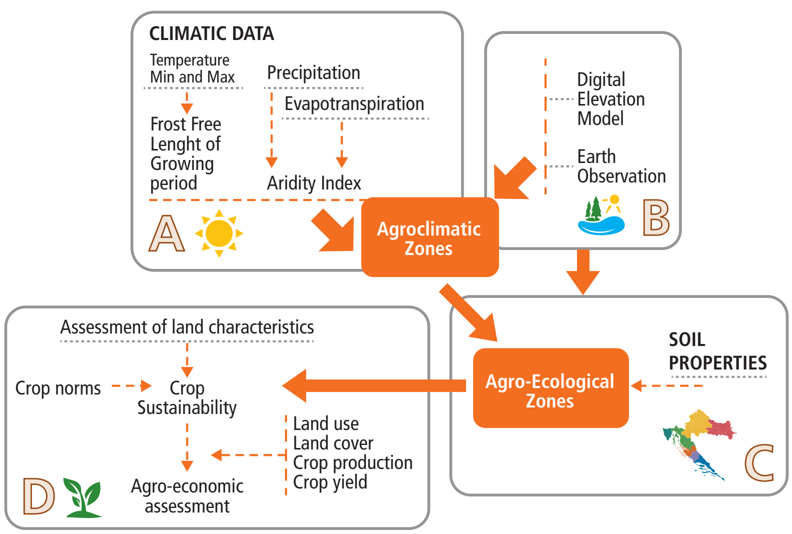
2 Rationale

This work represents the final stage of the analytical and strategic advisory work completed in the agri-food sector of Croatia under the STARS project. The STARS project was officially launched by Croatia's Ministry of Agriculture (MoA) and the World Bank in October 2018 with the objective to improve the capacity for evidence-based strategic planning by the Ministry. The project was developed in four interrelated stages: i) diagnostic analysis of agriculture, rural development and aquaculture in Croatia; ii) formulation of the National Agriculture and Rural Development Strategy; iii) development of an action plan, and iv) identification of priority areas for more in depth guidance, formulated as pilots. The sector diagnostic results were used as the evidence base for reaching out to sector stakeholders to gather their inputs regarding the key challenges facing Croatia's agri-food sector and the MoA policy priorities for the 2020-2030 period. This information was consolidated and reflected in the strategic objectives pursued by the MoA under its proposed National Agriculture and Rural Development Strategy (NARDS 2020-2030), which are to (i) increase the productivity and climate resilience of agricultural production; (ii) strengthen the competitiveness of the agrifood system; (iii) renew the rural economy and improve livelihoods in rural space; and (iv) stimulate agri-food innovation. Based on the evidence from the analytical work, the inputs from stakeholders and the priorities defined in the NARDS, two pilots were defined to further explore options for improving sector performance through strengthening linkages of agricultural producers to markets (pilot 1) and through spatial planning for optimizing sustainable production (pilot 2). The pilots were launched in March 2020 and applied the same approach as the one used for the STARS project overall, which is to use best practice methodologies that are both evidence-based and stakeholder-driven. This report presents the work carried out under Pilot 2.

This pilot supports Croatia with the consolidation of biophysical information with production and economic data as a first step in aligning its sector planning to the broader sustainability agenda of the EU. Reliable data on soils, climate, vegetation, and topography are paramount to support sustainable agricultural production and guide policy. Interestingly, most of these data are more widely available than what is generally realized. However, it is usually fragmented, at different scales or under the mandate of different entities. It also often requires some level of processing to generate the level of information needed to support agricultural decision making. This pilot aims at bringing the relevant climatic, terrain and soil as well as land cover and relevant socioeconomic information into a common repository to facilitate its application to support sustainable agricultural planning in Croatia. The pilot generated a comprehensive land resources dataset, consolidated into a National Agro-Ecological Zoning (NAEZ) spatial data platform, with key spatial digital layers integrated to facilitate agricultural production suitability assessments. It also demonstrated how these data sets can be used to answer specific questions and guide polices. Additional training was delivered to build the capacity in the use of the spatial data platform. The NAEZ as delivered is operational, but it requires a set of skills to optimize its use for policy purposes - a GIS-specialist able to manage and analyze the spatial data with the technical input from an agronomist and that of policy makers interested in targeting agricultural support. Both the Managing Authority and the Paying Agency of Croatia can benefit from integrating the NAEZ into their decision-making frameworks, for planning and implementation of support, respectively. The Ministry of Agriculture could also use this spatial data platform for policy analysis to inform regulatory changes.

This pilot applies the Agro-Ecological Zones (AEZ) approach as an instrument to support sustainable agricultural planning. The AEZ methodology is based on principles of land evaluation developed by FAO (FAO, 1976; FAO, 1984; FAO, 2007[22]). Agro-ecological zoning

FIGURE 1. Agro-Ecological (AEZ) Methodology Framework adapted from Ahmad, A. et al. (2019)[21]



21 Ahmad, A., Khan, M.R., Shah, S.H.H., Kamran, M.A., Wajid, S.A., Amin, M., Khan, A., Arshad, M.N., Cheema, M.J.M., Saqib, Z.A., Ullah, R., Ziaf, K., ul Huq, A., Ahmad, S., Ahmad, I., Fahad, M., Waqas, M.M., Abbas, A., Iqbal, A., Pervaiz, A., Khan, I.A. 2019. Agro-ecological zones of Punjab, Pakistan – 2019. Rome, FAO.

22 FAO, 1976. A framework for land evaluation. FAO Soils Bulletin 32. FAO, 1984. Land evaluation for forestry. FAO Forestry Paper 48 Mapping biophysical factors that influence agricultural production and rural vulnerability, FAO, 2007.

divides an area of land into smaller units, which have similar characteristics related to land suitability, potential production, and environmental impact (FAO/IIASA, 1991[23]). An agro-ecological zone is a mapping unit defined in terms of climate, soil, landform, and land cover with a specific range of potential and constraints for land use. The AEZ uses climatic, soil, terrain, and ancillary variables in a GIS platform to generate a spatially explicit assessment. The AEZ methodology has mostly been applied at the national level, linking it to earth observation information as the basis for supporting national agricultural planning decisions. AEZ was originally conceived as a tool for rural land-use planning and for land appraisal purposes. Over time, the concept has been extended to a range of applications including land degradation, irrigation suitability, environmental and climate change impact assessment of the agricultural sector. It has now also been adapted to develop national agro-ecological zonification, strengthen through the incorporation of remote sensing and earth observation data.

The pilot also focuses on consolidating information, knowledge, and capacity in Croatia. The prepared spatial datasets are the basis to support key land suitability analysis and to support several future applications. The key outputs of Croatia NAEZ were as follows:

- Delineated 10 agroclimatic and 13 agro-ecological zones for Croatia.
- Delineated the suitability of the territory of Croatia for the cultivation of selected crops (cherry and soybean) as an example of its application.
- Analyzed crop productivity by comparing existing situation against a potential arising from biophysical endowments (soil, topography, climate, water, agricultural land use, yield and profitability) using soybean as an example.
- Demonstrated on how climate change scenarios in temperature and precipitation will impact crop suitability using apple and cherry as examples.
- Capacity building in the use of datasets applying statistical analysis together with sample programming script for crop suitability was also delivered to technical staff and at more strategic level to policy makers in the Ministry of Agriculture.

Building capacity for converging and analyzing biophysical conditions and agricultural information can guide sustainable policies. Sustainable agricultural production hinges on the selection of crops that can produce maximum yields under optimal agro-ecological conditions and considering the ecosystem landscape. The development of agro-ecological zoning (AEZ) systems is the first step in identifying optimal production areas for different agricultural species. Although previous work on this topic has been attempted in Croatia, the numerous studies, research, and project results are not integrated and focus on different elements of this complex system. In this context, the current work contributes towards these efforts by developing an integrated dynamic spatial planning information dataset to support land planning for sustainable agriculture in Croatia. This work is also very timely, and it enables Croatia to more objectively assess the ambitions of the EGD in the context of its territory, while allowing a better alignment of agricultural support policies with optimal production potential in the different AEZs of the country. In terms of preparation of the current CAP operational program, it can specifically support Croatia identify opportunities to promote measures on organic production, agroforestry/silvopastoral/silvoarable systems, agri-environmental practices for better soil management strategies related to greening objectives. Furthermore, NAEZ can serve as a foundation to integrate additional spatial information on water availability complemented with economic and market analysis to support Croatia identify the crops and areas where investing in irrigation will make most sense. The climatic information can also be expanded to include climate change scenarios to support identify specific impacts to crops and regions as an input define regional adaptation strategies and climate investment needs. The pilot supports the capacity building within the Ministry of Agriculture of Croatia to enable the use of the National Agro-Ecological Zoning (NAEZ) spatial data platform to carry out agricultural assessments based on biophysical characteristics of the landscape.

23 FAO/IIASA, 1991. Agro-ecological land resources assessment for agricultural development planning. A case study of Kenya: Resources database and land productivity. Main report and 8 technical annexes.

2.1. Strengthening collaboration and building capacity

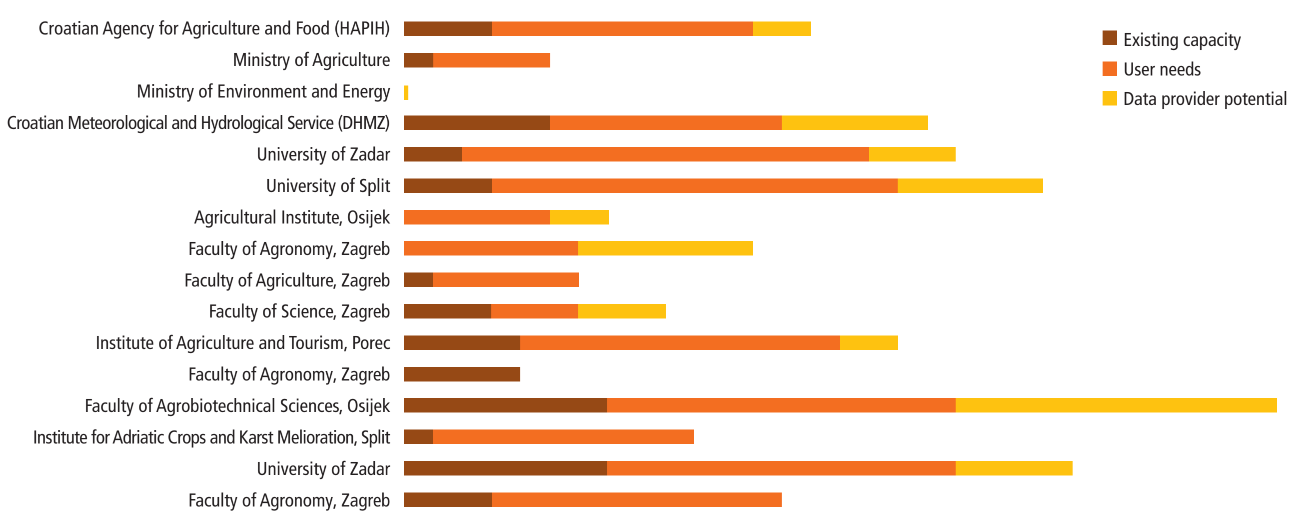
The data integration effort was complemented with strengthening institutional collaboration to allow for the technical sustainability of the outputs and information, including for future updates, and to maximize utilization of results to benefit information generation by key institutions in Croatia. To this effect, a Technical Working Group (TWG) was formed, led by the Ministry of Agriculture (MoA), and included the Croatian Meteorological and Hydrological Service (DHMZ), Faculty of Agronomy (Zagreb), Faculty of Agro-biotechnical Sciences (Osijek), the Croatian Agency for Agriculture and Food (HAPIH) and the State Geodetic Administration that produces digital terrain models. The TWG supported the identification and collection of the data necessary for the establishment of AEZ, the validation of the intermediate outputs and key AEZ findings, and functions as the knowledge holder of the NAEZ in Croatia.

A semi-structured survey to understand the baseline situation in the country in terms of data availability, existing technical capacity on geospatial and remote sensing data tools and data information availability for AEZ was carried out. Sixteen institutions responded (Figure 2). The analysis of the survey in general indicated the existence of significant data gaps, information fragmentation, limited capacity in some institutions while some others are better position to implement and disseminate the AEZ approach as discussed below. The most immediate needs expressed by respondents in terms of geo-spatial data are in three core elements: i) Digital soil layers and Climatic variables; ii) Spatial representation of crop productivity, irrigation, and crop coverage and iii) Spatial representation of crop yield.

Fragmentation of critical information is a challenge for its effective use for decision-making. Different institutions are collecting different data on relevant AEZ topics. The data is scattered, some digital data is missing and a single information repository coordinating the collection, receipt and exchange of AEZ-relevant data is absent. For example, DHMZ has been collecting climatic measurements from the agrometeorological stations and producing geospatial layers. Similarly, the University of Zagreb Geo-physics Department is also working on climate model and climate forecasts. Soil data is collected as measurement points by several institutions - Faculty of Agronomy of University of Zagreb, Institute of Agriculture Porec - and recently HAPIH has started to systematically monitor soil data as well. In terms of data availability, however, there is no digital soil database or soil information system available in Croatia, which makes soil data use difficult.

There is some installed capacity for biophysical data analysis in Croatia. The DHMZ, HAPIH, Department of Geography of University of Zadar and Geo-physics Unit of University of Zagreb have the highest capacity and technical knowledge on remote sensing, GIS and processing of

FIGURE 2. Summary of Survey Results



geospatial data. Interestingly most of the respondents are using some level of GIS, or satellite imagery for planning, analysis, and decision-making processes (11 replies out of 16) and most of the institutions (9 out of 16) have staff with skills for GIS software and systems use, GIS data collection, satellite imagery and processing of satellite imagery, climate modeling and land cover mapping.[24] This is an essential skill set for the institutionalization and management of the AEZ datasets in Croatia overtime, with most respondents having some level of capacity to do that effectively. Stakeholders expressed the need to increase their technical capacity in GIS technology, geospatial data processing and management as well as analysis of spatial information for agricultural uses. The survey also allowed to identify the Institutions with the higher benefiting potential from using the AEZ within the scope of their existing services from a utilitarian perspective as shown in Table 2.

Building strategic partnerships between MoA and institutions with established capacity is critical for the use of AEZ. Although, MoA's core responsibilities, activities and data management are highly relevant to the AEZ instrument, MoA is lacking some of the core skill set needed to operate the AEZ dataset. It is important to note that other departments within MoA may have the capacity to operate the dataset but did not respond to

TABLE 2. Summary of institutions with technical and organizational relevance of AEZ

Institution/Faculty	Department/Unit	Core responsibility	Core activities	Type of data	Tools
University of Zagreb Agronomy	Plant Nutrition Department	Moderate	High	High	
University of Zadar	Geography Department	High	High	High	High
Institute for Adriatic Crops and Karst Melioration	Director's Office	Low	Low	Low	Low
University of Osijek Agrobiotechnical Sciences	Food, Wine and Vineyards Department	Low	Low		
University of Zagreb Agronomy	Pedology (Soil) Department	High	High	High	Low
Institute of Agriculture and Tourism, Porec	Agriculture, Plant and Nutrition Department	High	High	High	Low
University of Zagreb Science	Geo-physics Unit	High	High	High	High
University of Zagreb Agronomy	Department for Plant Breeding, Genetics and Biometrics	Moderate	Moderate	High	Low
University of Zagreb Agronomy	Department for Management and Rural Entrepreneurship	Moderate	Moderate	Moderate	Low
University of Osijek Agricultural Institute	Department for Fruits	Moderate	Moderate	Moderate	Low
University of Split	Department for Marine Studies			Low	
University of Zadar	Department for Ecology, Agronomy and Aquaculture	High	High	High	Moderate

Source: World Bank STAR RAS Pilot 2 Survey. HIGH - Institutions/Departments which show high relevance between their core responsibilities and AEZ.[25] MODERATE-Institutions/Departments which core responsibilities are somewhat relevant to AEZ.[26] LOW - those Institutions having no relevant responsibilities and activities to AEZ.

24 Low score=no individual employed that has training and/or skills to handle basic spatial data and use GIS software. Moderate score = one individual with capacity to use GIS software and familiar with basic spatial data & remote sensing tools i.e. satellite imagery, land cover etc. High 2 or more individuals able to use GIS software and familiar with spatial tools and/or concepts.

25 Some examples are extension advisors can provide advice to stakeholders on crop selection and suitability such as extension services, DHMZ can provide targeted reporting on weather events based on AEZ regions, soil and land degradation assessment and monitoring, among others.

26 Periodical use of AEZ data for upgrading analysis and reports such as market productivity and prices; economic potential of certain crops by region in comparison to actual economic productivity, matching policies with crop production potential, monitoring the impact of existing policies on crop production.

the survey i.e Information Technology Department, the Advisory Service department, among others. Within this limitation and based on the information from this survey and the training carried out as part of this pilot, the recommendation is to house the NAEZ platform in HAPIH and the MoA allowing for the continuation of the use of the platform. It is also important to engage other line ministries and agencies overseeing physical planning, environmental, climate and agriculture implementation in the country such as DHMZ, Paying Agency, Ministry of Economy and Sustainable Development and Ministry of Physical Planning, Construction and State Assets among others to raise awareness of the knowledge platform and identify synergies for cross-sectoral use of the platform for spatial planning. Academic institutions including the University of Zagreb (Agronomy and Geospatial departments), Osijek Faculty Agrobiotechnical Sciences and University of Zadar will also benefit from using the platform for innovative approaches in partnership with the MoA. An important dimension of collaboration with a broader set of institutions is also the possibility for MoA to establish an *agricultural spatial planning network* which can then disseminate and build the capacity at local levels to influence land and agricultural planning and align it to MoA's vision and operational program. Additionally, the NAEZ spatial data platform can serve as a vehicle to promote collaboration with other key ministries and strengthen the position of the agricultural sector within the ongoing dialogue of circular economy, green agenda, and climate change, among others. This will be strategic if Croatia is to effectively deliver to the broader sustainability goals under its EU and Global commitments.

3 Building the Biophysical Knowledge: The NAEZ Croatia Data Sets

3.1. Compilation and preparation of data

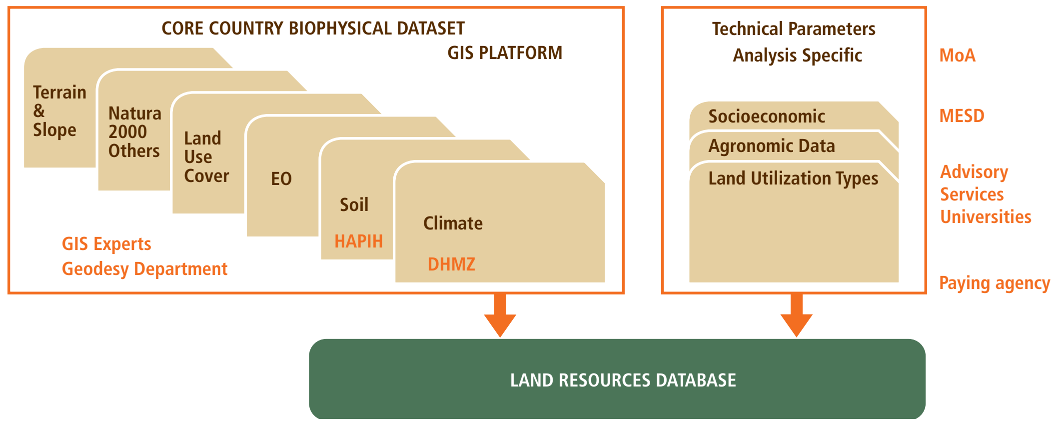
A land resources database collecting all relevant data was developed. Georeferenced base maps - land cover and vegetation, soil terrain, soil properties, climate, environmental constraints (Natura 2000 sites, flood risk areas, erosion susceptibility) and Earth Observation (EO) data - were processed to 30-meter resolution[27] or 1:60,000 maps scale. Additional non-spatial information complementing statistics and technical information on crop and agronomic data and socioeconomic data were also collected. Both sets of information were consolidated into a single repository and processed accordingly. A metadata file and a data catalog files identifying raw data, intermediary inputs and final outputs were produced and delivered to the MoA as part of the pilot (Annex 1 List of Intermediary Outputs).

3.2 Climatic data and agroclimatic analysis

Climate plays a critical role in determining suitable areas for agricultural production. Plants need light, temperature, and precipitation to grow. Continuous spatial data sets/maps of key climate variables such as minimum and maximum temperature, rainfall, humidity, wind speed and sunshine hours are essential. These climate parameters are used to compile agronomically

27 Each pixel is 30 meters on size representing an area of area of 900 square meter. The 30 meters are double and then multiply by 1,000 to get the equivalent map scale.

FIGURE 3. Land Resources Database



Note that layers on landslide susceptibility, Ramsar sites, global protected areas, flood risk are also included as part of the "other" in the Natura 2000 folder.

meaningful climate resource inventories including Length of growing period (LGP) for average daily temperatures above 0.5 and 10°C, and annual temperature profiles. This information is complemented with aridity index calculations.

Point data from the meteorological stations of Croatia was used to define the climatic layers. Although Croatia has an operating network of meteorological stations distributed throughout the country, continuous data on key agroclimatic variables in the country were not available at the time of this assessment. Point data from the meteorological stations network maintained by the DHMZ as part of the World Meteorological Organization Global Observing System were provided. A modeling of climate variables based on the point data measurements collected from 27 meteorological stations in Croatia for the 30-year period between 1988-2017 was carried out to produce continuous high-resolution (30 m resolution) raster layers to adequately capture the country's characteristics. This process generated close to 44 layers of climatic information (Annex 1) including annual average and monthly precipitation, temperature, evapotranspiration, annual average of the maximum and minimum temperatures and calculated layers on annual average frost free, length of growing period and aridity index. This information was first used to define the Agro-Climatic Zones of Croatia and later was applied in the crop suitability analysis. The technical details of the agroclimatic analysis are available in the stand-alone technical report Climate Layers Modeling and Definition of Agroclimatic Zones of Croatia.

The agroclimatic analysis was performed by integrating five variables (layers): Frost Free Period, Maximum air temperature in warmest month, Length of Growing Period (LPG), Aridity Index, and Altitude of terrain from DEM, applying the thresholds in Table 3[28] as verified with the DHMZ.

A total of 10 agroclimatic zones were identified for Croatia. It is important to note that these macro zones represent areas that are most viable for agricultural production because climatic needs meet general agriculture requirements. Approximately 10 classes representing 99% of the total area of the country were identified. Seven other smaller classes were also identified, and these were combined into a "no representative zone" class. The associated map illustrating the distribution of the 10 agroclimatic zones is presented in Figure 4 and the characteristics associated with each of the proposed agroclimatic zones is detailed in Table 4. Broadly, the map captures the three representative climatic zones associated with Croatia: Continental, Adriatic and Mountainous with some additional segmentation to represent the agricultural needs (i.e. not only climate).

28 It should be noted that the numerical value assigned to each class (class value) in the table makes it possible to identify the different combinations in the summatory product.

TABLE 3. Threshold and class value

Variable	Threshold	Class Value	Categories
Frost Free	143-179	1	Medium constraint
	180-296	2	No constraint
Maximum air temperature in warmest month (°C)	27.69-32.20	00	Thermal constraint
	16-27.68	10	No thermal constraint
Length of Growing Period (days)	197-269	100	No constraint
	270-348	200	Suitable
Aridity index	0.73-0.75	1000	Dry-sub humid
	0.76-1.97	2000	Humid
Altitude of terrain from DEM (m.a.s.l.)	0-125	10000	Very lowlands
	126-720	20000	Lowlands and Foothills
	721-1815	30000	Midlands & Mountains

FIGURE 4. Agroclimatic Zoning (ACZ) of Croatia

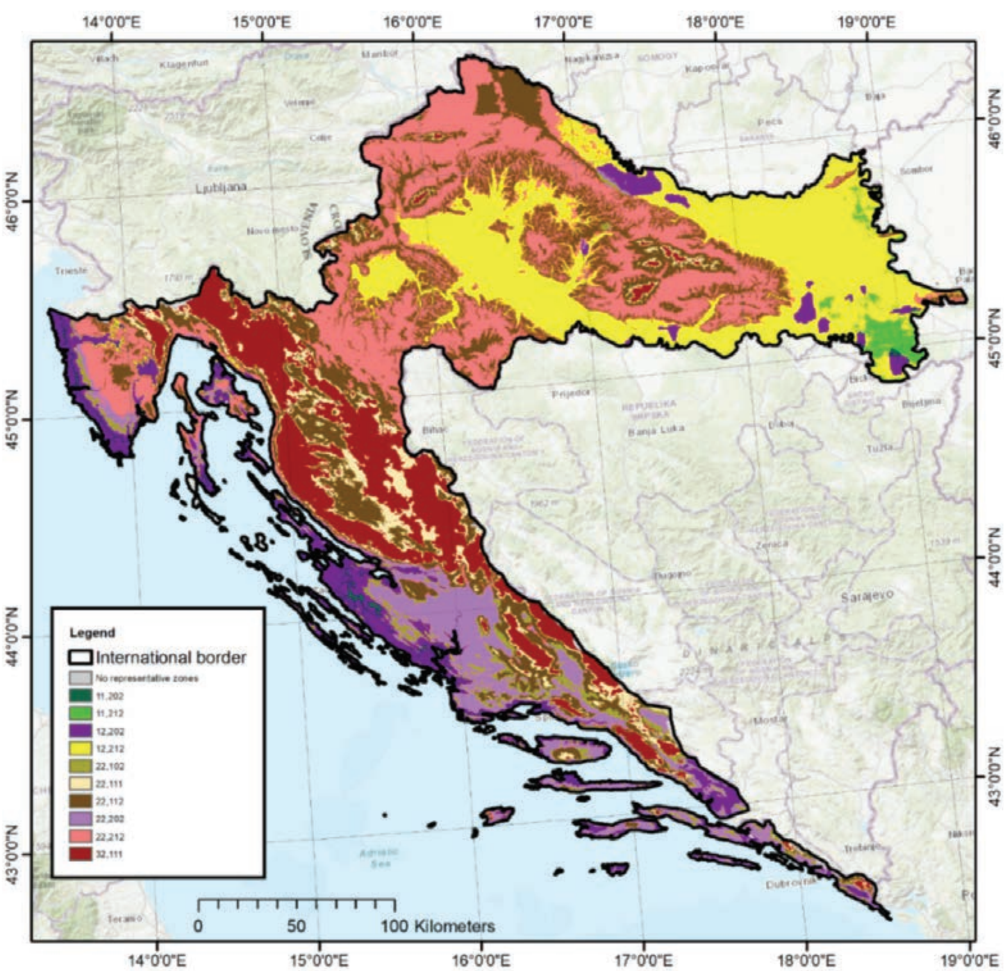


TABLE 4. Description of each Agroclimatic Zone of Croatia

ACZ	Class	Description	Area (km²)
1	11202	Very lowlands, dry sub-humid climate (aridity index 0.73 - 0.75), LGP 270-348 days, *thermal constrained very hot summer* and long Frost-Free period (180-296 days).	469
2	11212	Very lowlands, dry sub-humid climate (aridity index 0.73 - 0.75), LGP 270-348 days, without thermal constraint and long Frost-Free period (180-296 days).	624
3	12202	Very lowlands, humid climate (aridity index 0.76-1.97), LGP 270-348 days, *thermal constrained very hot summer* and long Frost-Free period (180-296 days).	4,049
4	12212	Very lowlands, humid climate (aridity index 0.76-1.97), LGP 270-348 days, without thermal constraint and long Frost-Free period (180-296 days).	11,835
5	22102	Lowlands and foothill, humid climate (aridity index 0.76-1.97), LGP 197-269 days, *thermal constrained very hot summer* and long Frost-Free period (180-296 days).	1,738
6	22111	Lowlands and foothill, humid climate (aridity index 0.76-1.97), LGP 197-269 days, without thermal constraint and *medium constraint related to Frost Free period* (142-179 days).	2,889
7	22112	Lowlands and foothill, humid climate (aridity index 0.76-1.97), LGP 197-269 days, without thermal constraint and long Frost-Free period (180-296 days).	9,899
8	22202	Lowlands and foothill, humid climate (aridity index 0.76-1.97), LGP 270-348 days, *thermal constrained very hot summer* and long Frost-Free period (180-296 days).	4,030
9	22212	Lowlands and foothill, humid climate (aridity index 0.76-1.97), LGP 270-348 days, without thermal constraint and long Frost-Free period (180-296 days).	13,136
10	32111	Midlands and mountainous, humid climate (aridity index 0.76-1.97), LGP 197-269 days, without thermal constraint and *medium constraint related to Frost Free period* (142-179 days).	6,365
	99999	No representative zone.	28
		TOTAL	54,861

In terms of agricultural production there are 4 agroclimatic zone (ACZ) that do not show climatic constraints to agriculture: 2 (light green, code 11212), 4 (yellow, code 12212), 7 (brown, code 22112) and 9 (pink, code 22212). The remainder of the zones show some level of constraint to agriculture from either frost or thermal aspects that are likely to impact agricultural production of highly sensitive crops.

3.3 Soil and terrain resources

Understanding soils and their composition is important for planning. Soil, as a resource and a core determinant of crop suitability, is critical for advancing sustainability policies and promoting economic feasibility of agricultural practices.[29] A clear understanding of soil and its spatial distribution over the territory is necessary to guide and inform adequate agricultural planning. A digital soil model/map is a critical tool that enables this process and, as such, is essential for the agro-ecological zoning and crop suitability assessment.

The pilot contributed towards the establishment of a digital soil map of Croatia. The preparation of the digital soil maps (DSM) began with the construction of a soil database from field soil data available in the country. This was a challenging undertaking given that soil data was not readily available and, where available, it was provided in different formats. Ultimately, data was successfully collected from five main sources (Table 5) and had to be processed into a comparable format. The review and gap analysis of existing soil field data was carried out and it clearly indicated a territorial imbalance in sample density with more information available for the Slavonia region when compared to the rest of the country.

29 Building Soils for Better Crops, Sustainable Soil Management. F. Magdoff & H. Van Es. 2009. USDA. https://www.sare.org/wp-content/uploads/Building-Soils-For-Better-Crops.pdf. Accessed March 2, 2021.

TABLE 5. Soil database points utilized in the preparation of the digital soil map

Source	Data points	Comment
Former State Directorate for the Environment and Nature Protection	2,199 pedological profiles	Sampled from 1963 to 1996
Faculty of Agriculture, Zagreb University	811 (0-30 cm topsoil)	Database of properties and quality of agricultural soils of Croatia.
Ministry of Economy and Sustainable Development	2,519 (0-25 cm topsoil)	From 1994 to 2004 for making of Geochemistry Atlas of Croatia
	742 (0-10 cm, 10-20 cm, 20-30 cm)	Locations were revisited during 2015-2016 and new samples taken and analyzed
HAPIH	6,067	Centre for soil -soil fertility testing for 2019 mainly in Slavonia (80%)
Piezometers network	812	Information review to improve accuracy of depth to bedrock parameter.

The technical details of the digital soil modeling required careful assessment and numerous cross-checks. The preparation of the soil classes and properties in a geo-referenced database (raster) was done using the 11,916 points[30] in combination with key predictor variables: the digital terrain model (DTM) and derivates, Sentinel-2 cloudless free seasonal mosaics (244 layers), Sentinel-1 monthly mosaics (48 layers), Geological map (lithological composition), Global Surface Water (GSW) 2019 dataset, Surface Soil Moisture (SSM) 2018, 2019 dataset and Climatic layers. In the case of the DTM, the State Geodetic Administration provided 1,512 files in CAD format which had to be processed to generate a 30m resolution DTM model for Croatia. The geological map was provided by the Croatian Geological Institute as 20 m grid and was re-sampled to 30m grid. The relevant soil physical (depth to bedrock, bulk density, soil texture, gravel content) and chemical (organic carbon, nitrogen, soil acidity, calcium carbonate, Phosphorous, Potassium, Calcium, Magnesium, electrical conductivity, cation exchange capacity) properties were then modeled. The regression analysis, carried out after all data was consolidated, shows overall good accuracy with varying degrees of quality related to both difficulty of modeling each variable and available sample size per soil property. The technical details of the digital soil modeling together with the model and program scripts to re-run the model are available in the technical report Digital Soil Map Modeling, with all data files provided to the Ministry of Agriculture (Annex 1).

The digital soil map of Croatia was developed to be globally comparable. The soil classification was modeled as per the World Reference Base (WRB) Soil Group (RSG) taxonomic system. This required first the translation of the Croatian soil classification system to the WRB system, this is an important output as it makes Croatian soil information comparable worldwide and enables Croatia to meet some of its international commitments (Figure 6).

3.4 Additional layers for the NAEZ methodology

The CORINE land cover for Croatia for 2018 was downloaded from available public sources and re-processed to 30m resolution to capture mainly the agriculture, grassland and forest cover. The Natura 2000, Ramsar sites and world database of protected areas mask, land slide susceptibility and flood risk management (obtained from Croatian Waters) were also collected and included as part of the land resources database as these are important parameters to assess potential environmental constraints.

30 With a varying number of points available per soil property, as variable sets of measurements were performed upon soil samples collected at their respective locations.

FIGURE 5. Sample of maps generated as part of the digital soil mapping process

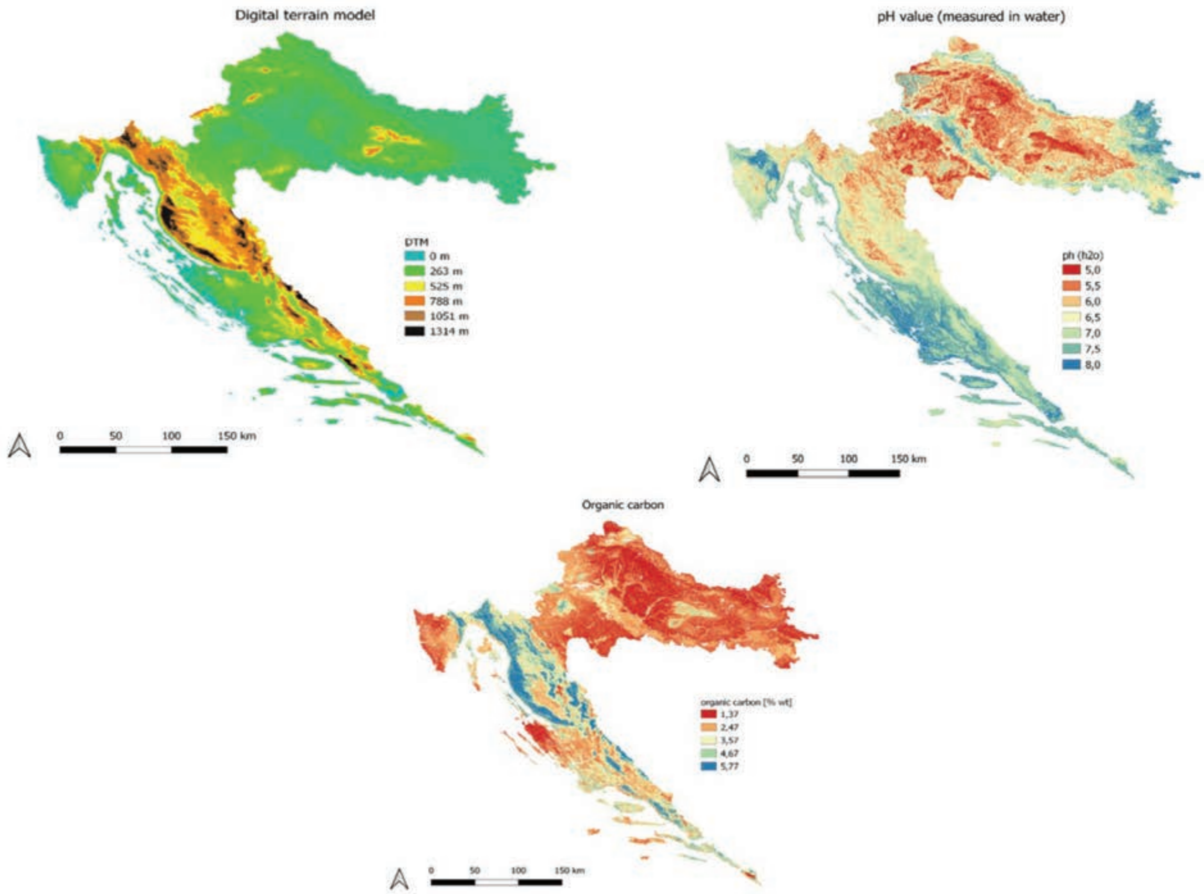
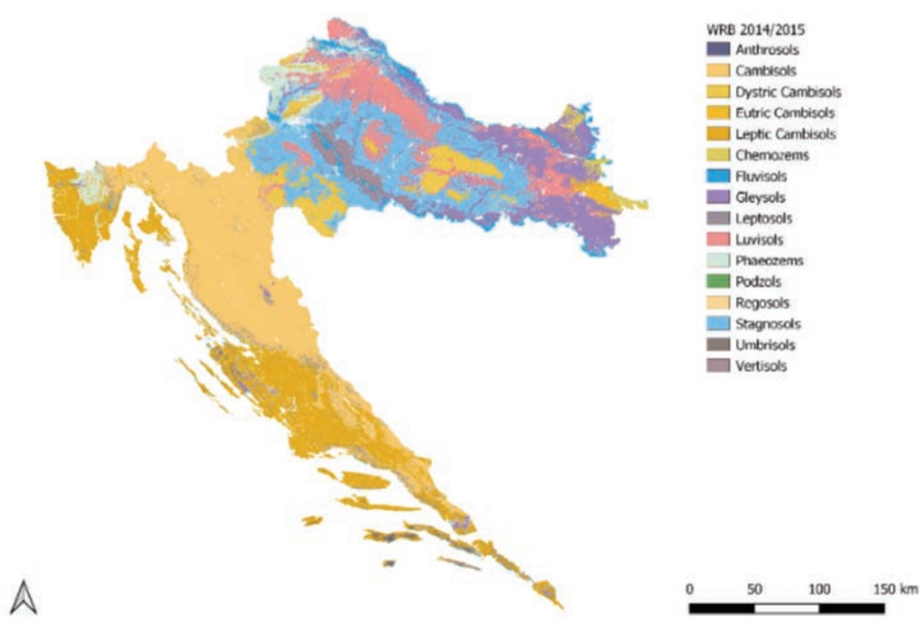


FIGURE 6. Croatian WRB Soil Classification map



3.5 Crop information and requirements

Seven crops - soybean, cherry, corn, olives, apple, sunflower and grapes - were identified as priority crops for Croatia in the stakeholder survey. From this list, the MoA selected 2 crops: soybean, and cherry, to use as case studies for the application of the NAEZ spatial data platform to assess crop suitability, yield gap and economic land suitability from closing the yield gap. Beside the geospatial information, the following data was collected to carry out these assessments:

- **Production data.** Statistical data, agricultural surveys, and relevant information from the Paying Agency collected as part of the STARS project was used. Disaggregation of information at the subnational level was limited for yield, production cost and market prices for commodities. However, according to national data sources, differences in yield are not significant given that most of the production of specific crops takes place in the same region. Production costs are similar within regions and crops. Price data was obtained from the MoA agricultural market price information system and from interviews with producer organizations. Data on agricultural area per county is available from the Paying Agency for the period 2016 to 2020 and was used to estimate production using the average annual national yield, which was obtained from the Croatian Bureau of Statistics for the same period (2016 to 2020).
- **Characterization of farming systems** (land utilization/management types or LUT). Information was only available at the national level and disaggregation at the subnational level was not possible. The summary of potential LUTs and thresholds are included in the land resources database as a reference and to guide future use.
- **Agronomic information.** As part of the suitability analysis is very important to obtain key biophysical crop requirements in terms of both optimum and limiting conditions for soil properties (texture, electric conductivity, soil organic matter, calcium carbonate, rooting depth and pH range), climatic condition (water requirements, evapotranspiration, temperature and rainfall), and environmental constraints, length of growing period, terrain (slope) and cropping calendar. This information is very specific to the country context and was obtained either from local literature or from national experts (agronomists). The biophysical attributes and parameters related to the production of the selected crops are summarized in Annex 1.

4 Application of the Croatia NAEZ Spatial Data Platform to Support Evidence-Based Decisions

Compilation and preparation of the biophysical, climatic and soil databases is the most data intense and time-consuming part of building the NAEZ spatial data platform. These datasets will continue to be relevant in the future as biophysical processes take longer periods of time to change. Some level of update or improvement over time was identified as important by stakeholders. Once these databases are created and placed in a common repository, their use to support analysis is a much more simplified process. The pilot demonstrated the potential use of the datasets through the following assessments. It is important to note that the AEZ assessments presented below provide only a guidance on crop suitability based on a set of biophysical criteria. They do not consider socio-economic, economic and value chain/logistic considerations. Suitability alone should not be used to define if a crop should be grown or not but rather be used as a guidance on biophysical potential. Economic factors can be incorporated into the assessment to provide an integrated decision-making framework. The suitability assessments presented here are intended to demonstrate the usefulness of the spatial data set platform as an instrument to support public decision-making by integrating soil and climate characteristics into sectoral and local development strategies.

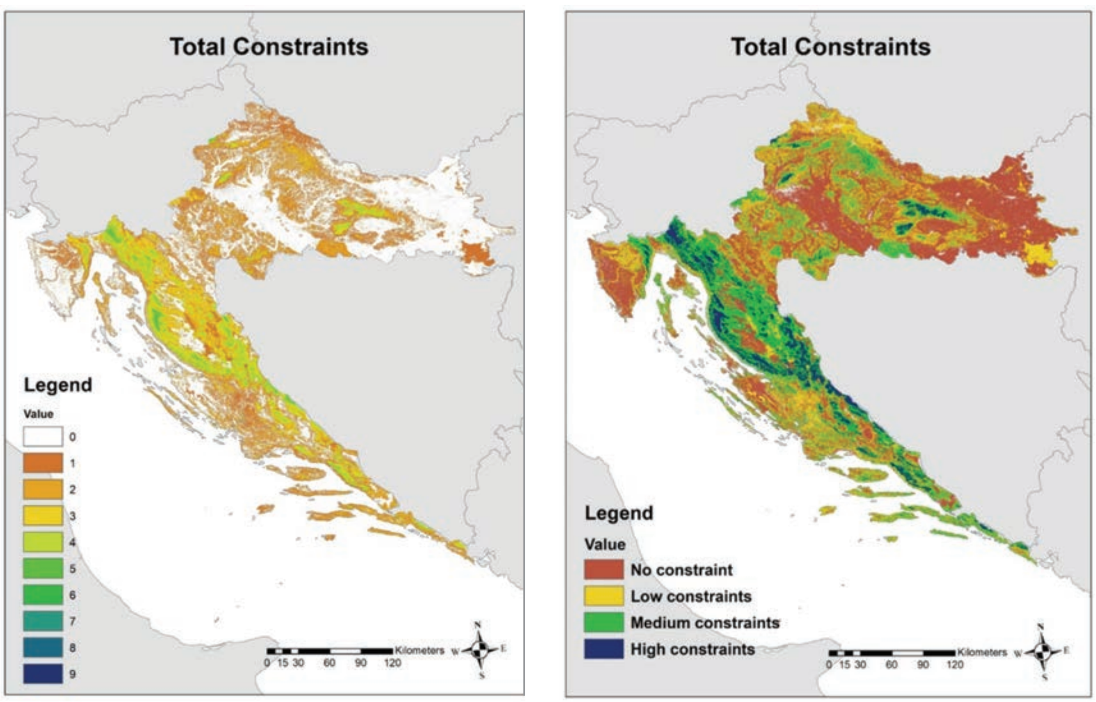
4.1 Assessment of biophysical constraints and definition of Agro-Ecological Zones

The Agro-ecological Zonification methodology provides the means to assess the suitability of land for agricultural production at the macro level based on general climatic, land and soil suitability factors that respond broadly to crop needs. Potential constraints may exist in the territory that limit or nullify agricultural production. As part of the agro-ecological zonification constraints arising from land use, soil, climatic and water availability, environmental characteristics (Natura 2000, Ramsar Sites, land slide susceptibility and flood risks), and terrain are first evaluated to identify the areas where the true potential for production exists and where sustainable (economically, environmentally, and socially) agricultural production systems could be promoted. The AEZ map allows to quickly visualize those regions that hold the best agricultural potential in the country, currently and in the medium term, with updates required to capture changes in climate. The Joint Research Center (JRC) in its assessment of areas under natural constraint recommends that climatic data be updated every 10 years (decennial).

4.1.1 The analysis of constraints

The analysis of constraints is primarily based on demarcation provided in the Ordinance on Determination of Areas with Natural or Other Specific Constraints Official Gazette 118/18[31] (ANC Ordinance) for Croatia and EU Regulation 1305/2013 Article 32 Designation of areas facing natural or other specific constraints, Annex 3 Biophysical Criteria for the Delimitation of Areas Facing Natural Constraints.[32] The detailed constraints and thresholds applied in the assessment are summarized in Annex 1. The constraints were first assessed individually. Each individual constraint was then overlaid, and a combined total constraint map is generated (Figure 7). This total constraint map illustrates the distribution and level of constraint found throughout the territory. The constraint raster map is then re-classified into 4 classes using GIS functions to group the constraint values into no constraints (0 constraints), low constraints (1), medium (2), and high constraints (3-9). The results indicate that approximately 43% of the territory of Croatia is constraint free while 28% has low level of constraint (yellow), 23% are medium constraint (green) and 6% only is high constraint (Figure 7 and Table 6).

FIGURE 7. Total constraints to agricultural production in Croatia



31 Pursuant to Article 132, paragraph 1 of the Agriculture Act (Official Gazette 118/18), the Minister of Agriculture issued Ordinance on Determination of Areas with Natural or Other Specific Constraints.

32 https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32013R1305

TABLE 6. Summary of areas under constraint

Constraint level	Area (%)
No constraint	43
Low constraint	28
Medium constraint	23
High constraint	6

4.1.2 The delimitation of the Agro-Ecological Zones (AEZ)

The agro-ecological zonification process combines areas that have similar limitations and potentials to support agriculture and aggregates them at the national level. Broadly, the AEZ allows to easily identify the distribution of areas having agricultural capability from those that may pose significant limitations. The combination of geospatial layers on agroclimatic zones with those related to limitation on agricultural production derived from soil and terrain constraints, as described above, was used to generate the Agro-ecological zones of Croatia (Figure 8).

The analysis identified a total of 13 Agro-Ecological Zones in Croatia. The main characteristics for each zone are summarized in Table 7. The total suitable area for agriculture comprises 40% of the territory of Croatia; however it is important to note that some of this area is currently under forest or grassland and not readily available for agricultural production. The largest agro-ecological zone in Croatia (zone 4) is around 1,071,640 ha (20% of the territory). It has no soil or climatic constraints and is overall suitable for agricultural production. The land in this zone is currently used for agriculture, forest, and grasslands. The second largest zone (zone 9) comprises more than 19% of the Croatia´s territory (1,006,200 ha) and its main current land use is forest land. Other suitable zones for agriculture are zones: 2, 3, 5 and 7 and main current land uses are agriculture, forest and grasslands. Other zones indicate potential constraints (climatic, edaphic or terrain) to agriculture reducing their economic viability for production.

FIGURE 8. Agro-Ecological Zones (AEZ) of Croatia

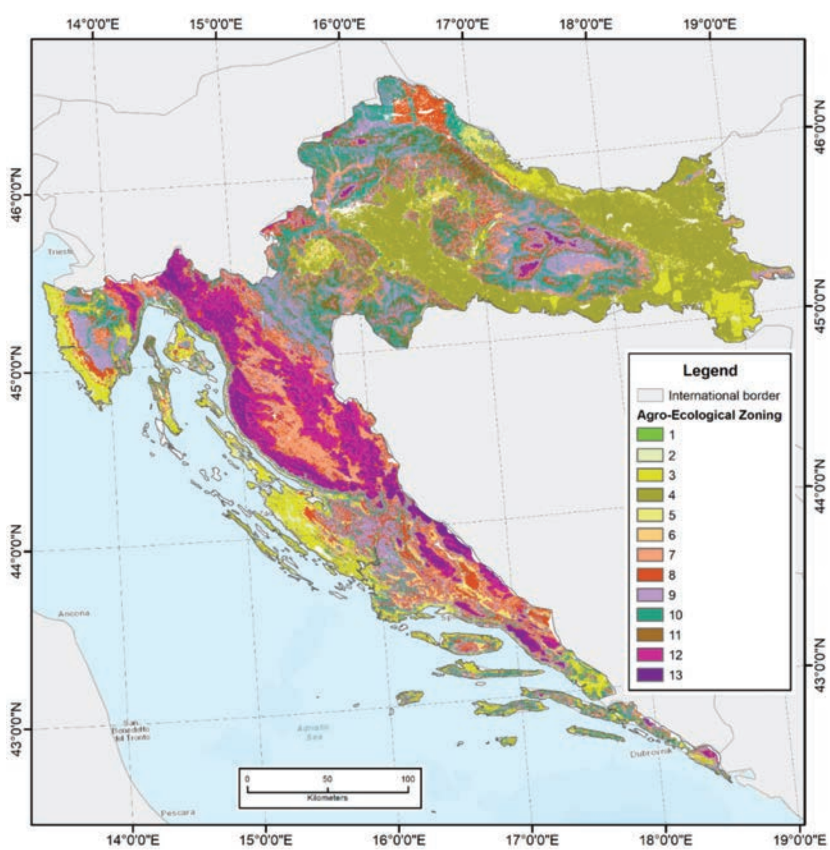


TABLE 7. Characteristic of variables in each of the Agro-Ecological Zones

AEZ	Area (%)	ACZ	Constraint level	Main constraint	Aridity index	LGP average	Terrain altitude (m.a.s.l.)	Frost free average	Current main land use
1	0.01	0	1	No representative area (very small size)					
2	0.48	1	1	Aridity	0.73-0.75	270-348	Very lowlands < 125	180-296	Agriculture/Forest
3	5.8	3	0	None	0.76-1.97	270-348	Very lowlands < 125	180-296	Agriculture/Forest/ Grassland
4	20.4	4	0	None	0.76-1.97	270-348	Very lowlands < 125	180-296	Agriculture/ Grassland/Forest
5	4.1	4	1	CEC	0.76-1.97	270-348	Very lowlands < 125	180-296	Agriculture/Forest/ Grassland
6	1.3	5	1	Soil pH	0.76-1.97	197-269	Lowlands and foothills 126-720	180-296	Grassland/ Agriculture/Forest
7	9.5	7	0	None	0.76-1.97	197-269	Lowlands and foothills 126-720	180-296	Agriculture/Forest/ Grassland
8	10.7	7	1	CEC	0.76-1.97	197-269	Lowlands and foothills 126-720	180-296	Forest/Grassland/ Agriculture
9	19	9	0	None	0.76-1.97	270-348	Lowlands and foothills 126-720	180-296	Forest/Agriculture/ Grassland
10	12.4	9	1	Slope	0.76-1.97	270-348	Lowlands and foothills 126-720	180-296	Forest/Agriculture/ Grassland
11	4.1	9	2	Soil pH, Slope	0.76-1.97	270-348	Lowlands and foothills 126-720	180-296	Forest/Grassland/ Agriculture
12	7.6	10	3	Soil depth, Slope, Frost	0.76-1.97	197-269	Midlands and mountains 721-1815	142-179	Forest/Grassland
13	4.5	10	3	Soil depth, Slope, Frost	0.76-1.97	197-269	Midlands and mountains 721-1815	142-179	Forest

4.2 Crop suitability analysis under rainfed conditions

Knowledge of naturally suitable locations for the cultivation of a particular crop is a basis to support a more effective natural resource management and sustainable agriculture planning. Mapping agricultural suitability using geographic information systems allows to spatially match crop requirements and/or constraints with prevailing agroclimatic, agro-edaphic and terrain characteristics of the land to support the development of more efficient production systems. In the case of Croatia, where agricultural productivity is low relative to other EU countries,[33] crop suitability can contribute to better target sustainable productivity gains. An analysis of the fruit subsector in Croatia carried out under the STARS project identified the need for a regionalized fruit production strategy to clearly mark the regions/subregions that have the highest suitability for growing fruit species or similar fruit varieties. This regionalization is considered essential for increasing yield, fruit quality and diversification into less represented species. In this context, the suitability analysis for cherry was performed using the Croatia NAEZ spatial data platform. In addition, the NAEZ information was combined with the specific agronomic crop requirements to define the most suitable areas for producing soybean in the country.[34]

Fruit orchards cover around 30,500 hectares in Croatia. Cherry production is among the top 3 fruit crops produced

33 Logatcheva, K., M.A. van Galen, S.R.M. Janssens, G.M. Splinter, 2018. Business opportunities for Croatian fruit and vegetables growers. Wageningen, Wageningen Economic Research, Report 2018-002. 102 pp.; 55 fig.; 11 tab.; 13 ref.

34 Cherry and soybean were selected as crops for the application of the tool. These are examples on how the suitability analysis can be helpful to make production and policy decisions. But it is only one element of a complex decision making framework, which should also consider economic and social factors.

in the country including both sweet and sour varieties. Sweet cherry is mainly grown in home gardens and on small plantations. The ten-year average yield (2010-2019) for sweet cherry is estimated at 2.16 tons per ha and for sour cherry 2.75 tons per ha (FAO, 2021). Domestic production is insufficient to meet demand for fresh table cherries and significant imports are needed. Sour cherries production is growing in terms of cultivated area and volume, which is likely driven by the demand for processing of cherry-based alcoholic beverages for worldwide export and non-alcoholic drinks, like juices. The gross margin for sweet cherry production is almost double than the gross margin for sour cherry.[35] This is primarily due to the price difference responding to the higher quality required in fresh produce when compared to a processed good.

According to the Croatian Bureau of Statistics, the harvested area of soybean was estimated around 80,000 ha in 2020 with an estimated production of 232,000 tons. This is after the production area for soybean almost doubled in 2015 in response to financial incentives stemming from its eligibility for voluntary coupled support as well as nitrogen-fixing crop under the ecological focus areas under the CAP in 2014/2015.[36] Croatian soybean exports also show an overall increasing trend although this has been coupled with an increment in feed meal imports. Croatia has one of the highest yields (3.11 tons per ha) in soybean in Europe which is a good indication of its production potential.[37] Soybean is highly suitable for organic production and can be one potential option to increase organic farming in the country. Furthermore, recent developments to build a GMO-free soy processing facility in the country are important to support value addition and create opportunities for accessing differentiated market which can incentivize improvements in productivity overall.

To carry out the suitability assessment, first information on the crop requirements/constraints associated with biophysical attributes was identified. The biophysical spatial attributes identified for each of the selected crops and their thresholds are summarized in Annex 1. Suitability layer was generated by superimposing the crop requirements/constraints information with the biophysical layers, i.e. soil texture, min temperature etc.) which are part of the NAEZ spatial data platform for Croatia. Each layer is re-classified into suitability classes: very suitable, suitable, medium suitable, low suitable and marginal/unsuitable areas. In the case of soybean, the final suitability layer is presented only in agricultural lands (CORINE 2018). All other land uses (forest, natural vegetation, grassland, artificial areas, etc.) are excluded to safeguard against identifying suitability in sensible areas. In the case of cherry suitability, the potential area was disaggregated according to current land use (agricultural, forest and grasslands), as cherry plants can be incorporated in reforestation/afforestation/silvopastoral systems and in Natura 2000 sites if autochthonous varieties are promoted. The results are summarized in Table 8 for both cherry and soybean.

4.2.1 Cherry suitability

Cherry suitability is high in agricultural areas in the central part of Lika-Karlovac, central Istria, southern part of Slavonia and northern parts of central Croatia (Figure 9 Map A). It is important to note that in these areas, cherry can have an important contribution in balancing the agricultural landscape with the environment. Cherry trees can help protect soil and mitigate leaching to support managing areas highly susceptible to soil erosion and nitrate leaching. Pruning biomass materials from higher density orchards (300 to 400 trees per ha) of sweet cherry and sour cherry can also generate around 2 tons of pruned biomass per ha which is often burnt and contributes to greenhouse gas emissions and air pollution.[38] Support to farmers to access equipment and knowledge to manage these co-products can promote income diversification while also pursuing climate mitigation benefits.

Cherry is highly valuable for its fruit and timber species and often used as a tree in temperate agroforestry

35 Based on Croatian Advisory Service, Gross Margin Calculations. https://www.bordeaux.inra.fr/cherry/docs/dossiers/Activities/Meetings/21-23_11_2012_WG_and_2nd_MC_Meeting_Palermo/Day_1/07_Njavro.pdf

36 https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52018DC0757&from=EN

37 Dragan, Terzic; Vera Popovic; Mladen Tatic; Vera, Djekic, Vladan Ugrenovic, Slobodan Popovic, Pasaga Avdic. Soybean area, yield and production in the World. International ECO-conference Novi Sad Serbia, 26 to 28 September, 2018.

38 N. Bilandzija, N. Voca, T. Kricka, A. Matin and V. Jurisic. Energy Potential of fruit tree pruned in Croatia. *Spanish Journal of Agricultural Research* 2012 10(2), pp 292-298.

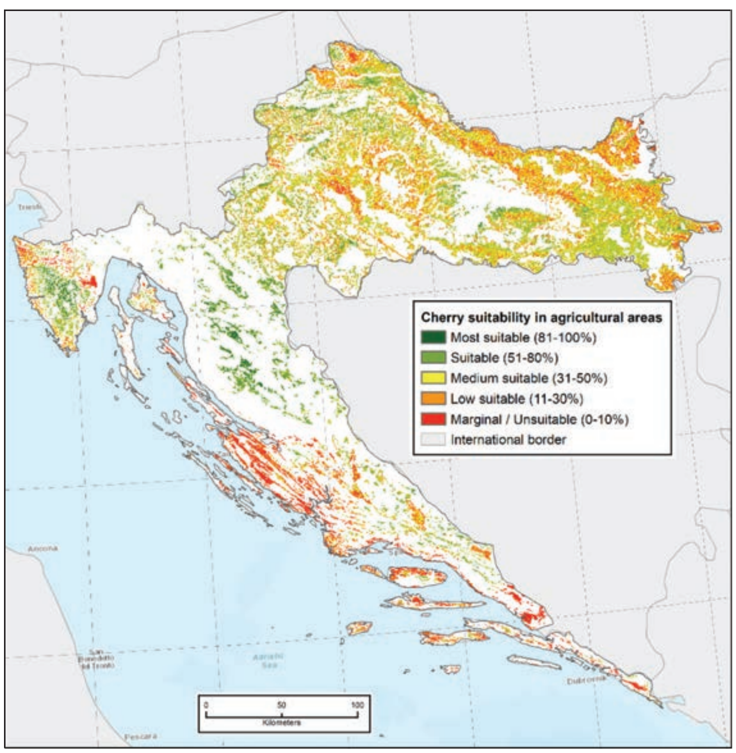
TABLE 8. Summary of land area with suitability for the selected crops, hectares

Suitability level	Cherry			Total* suitable area for Cherry (a + b + c) (ha)	Soybean (ha)
	(a) Agriculture current land use coverage (ha)	(b) Forest current land use coverage (ha)	(c) Grassland current land use coverage (ha)		
Most suitable (81-100%)	63,428	95,984	69,794	229,206	810,240
Suitable (51-80%)	465,296	669,223	372,223	1,506,742	655,790
Medium suitable (31-50%)	647,069	631,688	331,398	1,610,155	414,470
Low suitable (11-30%)	471,690	375,121	239,450	1.086,261	234,380
Marginal Not suitable (10%)	249,563	183,736	204,952	638,251	32,850

*Sum of suitability in Agriculture, Forest, Grassland/Pasture.

systems in Europe.[39] Furthermore, agroforestry under the Farm to Fork Strategy and under the new "eco-schemes" of the CAP is one alternative to increasing the sustainability of agricultural areas and enhance pasture and forestry management.[40] Additionally, the Biodiversity Strategy recognizes the multiple environmental benefits that agroforestry systems provide. Cherry is one option to support efforts for diversifying the landscape and enhancing biodiversity. The suitability assessment of cherry was disaggregated based on current land use (Corine, 2018) to highlight the suitability of cherry in forested (Figure 9 Map B) and pastureland areas (Figure 9 Map C). Around 39% of forest land is found to be most and suitable for cherry.

FIGURE 9. Crop suitability of cherry in agricultural land (Map A)



39 Y. Reisner, R. de Filippi, F. Herzog, J. Palma. 2007. Target regions for silvoarable agroforestry in Europe. *Ecological Engineering.* Vol 29 (4), 401-418 pg.

40 https://www.quickscan.pro/sites/default/files/inline-files/deHaan(2020)_wildCherrySuitabilityOnIrishPastures.pdf

FIGURE 9. Crop suitability of cherry in forestland (Map B)

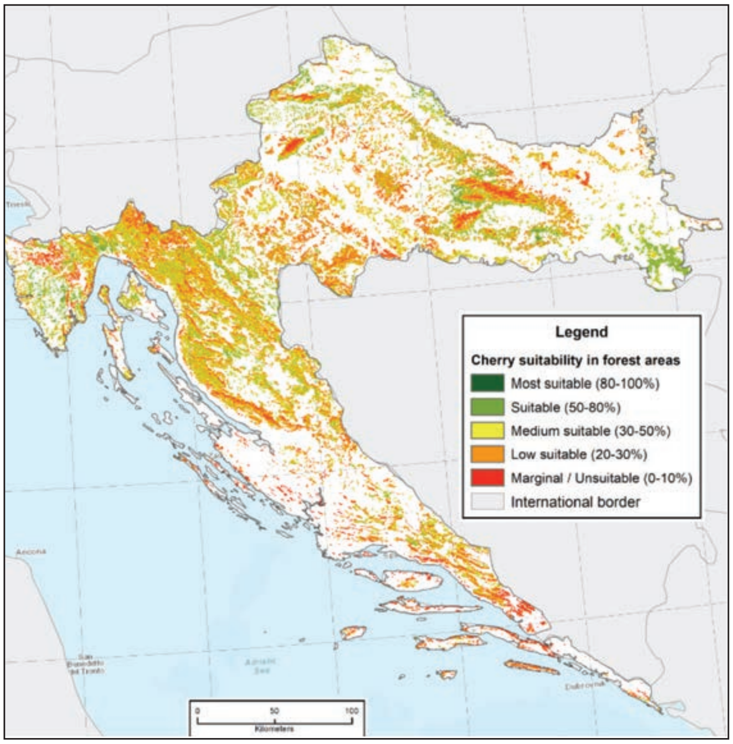
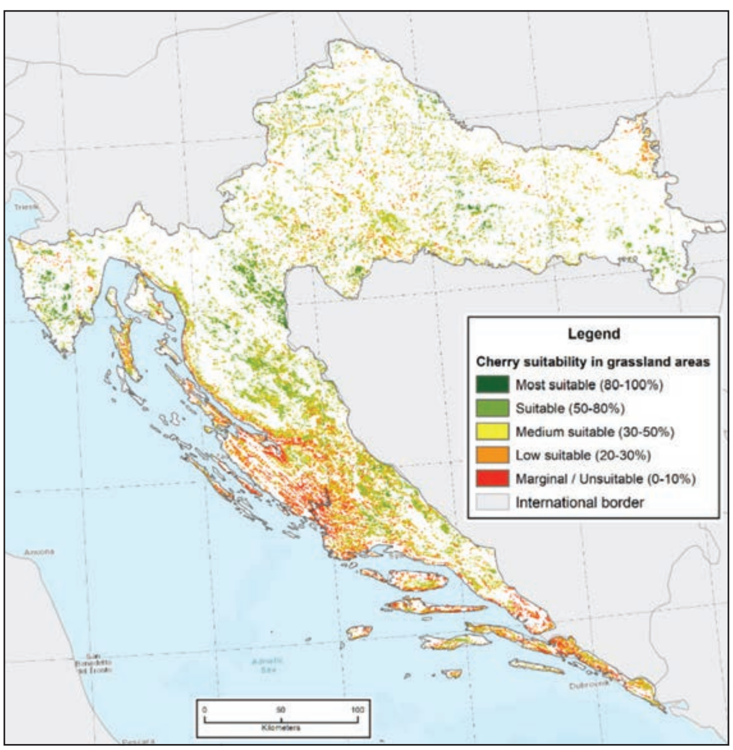


FIGURE 9. Crop suitability of cherry in pastureland (Map C)



Likewise, around 36% of pastureland shows good suitability for cherry.

This analysis shows the biophysical potential for cherry in Croatia, which is important, but socioeconomic aspects would also need to be considered to maximize this potential in economic terms. Strategies to promote cherry cultivation and other similar varieties in key strategic locations in the country linked to agri-environmental and greening incentives are one example of how strategic planning can help guide agriculture with a vision of linking production to sustainability goals.

4.2.2 Soybean suitability

The highest suitability for soybean is in the North and North-east regions of Croatia (Figure 10). The most suitable area is around 810,000 ha. Soybean as a crop can support multiple objectives in Croatia. Soybean is highly suitable for organic production and can easily fit into organic farming schemes which can contribute towards organic agriculture production goals. Soybean is also a nitrogen-fixing legume and an important crop rotation option due to the favorable carbon-nitrogen balance in harvest residues. The use of fungicides is rarely needed to treat soybean reducing the cost of production and contributing positively to environmental goals. Furthermore, considering Croatia's yields are among the top in Europe, the country is well positioned to benefit from the potential EU market opportunities for soybean and particularly non-GMO products.

Given the high susceptibility of soybean to soil erosion risks during its first months, broader aspects such as soil type, preceding crops, residue management and susceptibility of the location to erosion need to be considered to assess erosion risk. Wind erosion is also another factor to consider since it can affect soya bean production prior to the beginning of flowering. For this reason, a layer identifying the spatial propensity to soil and wind risk were also generated and can be used in combination with the suitability assessment to identify areas that may be suitable yet adequate consideration to overcome erosion risk may need to be implemented (Figure 10, A and B). In Figure 10B, the areas highlighted in red are those that are also at high risk of erosion and

FIGURE 10. Soybean crop suitability in agricultural land (Map A)

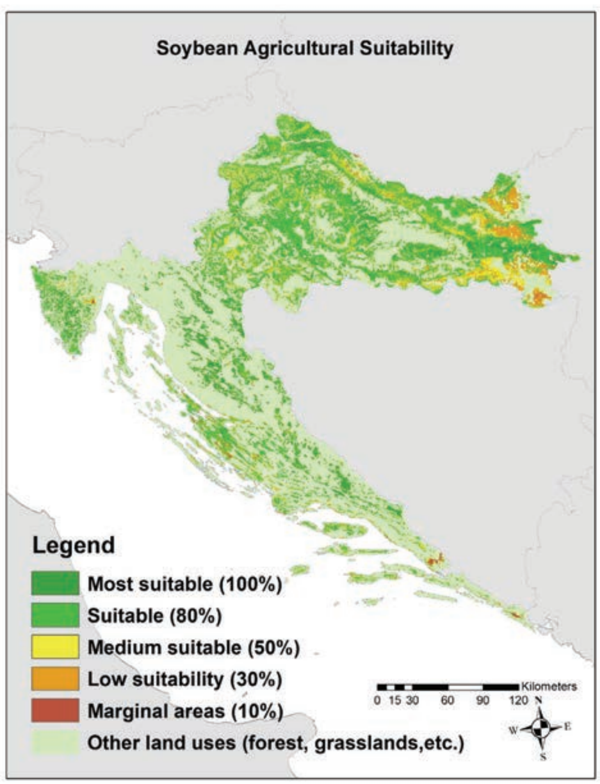
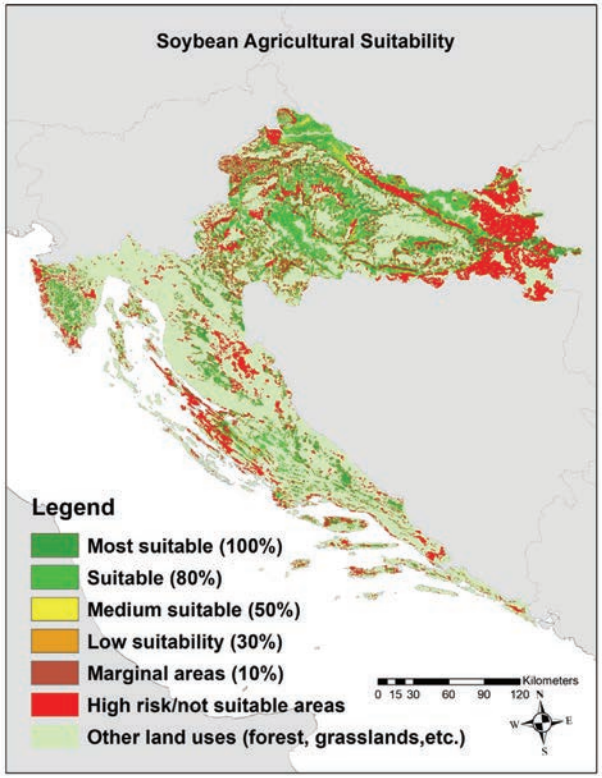


FIGURE 10. Soybean crop suitability with erosion risk in suitable areas (Map B)



therefore although suitable, they represent an environmental risk.

4.2.3 Towards an agroeconomic zonification

From an agronomic perspective, the comparison between the attainable potential yield and the current yield provides an indication of the untapped production potential of a crop from a biophysical perspective. This difference is referred as the yield gap. Yield gap estimations provide important information on the scope for production increases on existing agricultural land through better farming systems, improved farm management practices and enabling policies (Van Ittersum, et al. 2013[41]).

From an economic perspective, it is key to understand what economic benefits could be realized by closing the yield gap. Production cost and returns can show the weak and strong points of differing farming production typologies to help decide which crops represent better economic opportunities. To conduct this analysis, disaggregated information on crop yields, farmgate prices and production costs is needed. Unfortunately, data on disaggregated production costs at subnational level were not available. This leaves only the possibility of using the estimated crop yield at county level and market price information to calculate a gross margin for use for agroeconomic zoning. Although this is a simple and first approximation indicator, it provides a general idea of the potential economic implications. The yield gap and economic suitability analysis was carried out for soybean to demonstrate its applicability.

4.2.3.1 Yield gap assessment

To establish the potential attainable yield, historical data in FAO Stats for the period of 1992-2019 was reviewed. During this period, the highest yield attained in Croatia was 3.2 tons/ha, this was set as the ceiling

41 M. K. van Ittersum, K. G. Cassman, P. Grassini, J. Wolf, P. Tittonell, Z. Hochman. Yield gap analysis with local to global relevance—A review, Field Crops Research, Volume 143, 2013, Pages 4-17.

benchmark for potentially attainable yield. The potential attainable yield was adjusted to each suitability class as an index of land productivity (Table 9). Disaggregated actual yields at the regional level in Croatia were not available and had to be calculated based on harvested data obtained from the Paying Agency at the county level and on production estimates (Table 10). The yield potential was calculated as the difference between potential yield adjusted for each suitability class (Table 9) and the actual yield (Table 10). The values were reclassified into low yield gap and high yield gap. Figure 11, Map B indicates the locations where the actual yield is significantly below potential attainable yield.

4.2.3.2 Gross economic potential

The gross potential income is calculated by multiplying the potential attainable yield by the farm gate price. The producer price was only available at the national level and it was not possible to disaggregate it at the subnational level. Producer prices for soybean have been stable over the past 5 years at an average of EUR 0.32 per kg.[42] Unfortunately, production cost data disaggregated per region and yield were not available to generate a net benefit. Further resolving the limitations of the production cost data could help refine a detailed agroeconomic zonification.

From a gross economic benefit perspective, closing the yield gap has high revenue potential in most of the suitable areas (Figure 12). Findings from the technical efficiency analysis (part of the diagnostic work of STARS RAS) suggest that the mean efficiency of the average farm in Croatia is around 0.30 indicating that it can produce the same output using 70% fewer inputs under the available production technology. These findings indicate that there is an opportunity to close the yield gap while reducing the cost of inputs as well. However more detailed analysis is required to build a stronger economic case. In addition, the role of irrigation can be considered, as yield estimates are for rainfed condition and while Croatia is a water rich country, availability of rainwater during the growth season can be a limiting factor. In Slavonia, an irrigation study of soybean indicated that supplemental irrigation could increase grain yield by 7.4% compared to rain-fed production and ensure stable yields.[43]

TABLE 9. Adjusted potential attainable yield according to suitability class

Value	Suitability	Attainable yield
1	Most suitable (100%)	3.20
2	Suitable (80%)	2.56
3	Medium suitable (50%)	1.60
4	Low suitable (30%)	0.96
5	Marginal areas/Not-suitable (10%)	0.32

TABLE 10. Actual soybean yield (tons/ha)

County	Average yield
Bjelovarsko-bilogorska	2.68
Viroviticko-podravska	2.67
Pozesko-slavonska	2.68
Brodsko-posavska	2.67
Osjecko-baranjska	2.67
Vukovarsko-srijemska	2.67
Karlovacka	2.65
Sisacko-moslavacka	2.68
Primorsko-goranska	2.66
Licko-senjska	0.00
Zadarska	0.00
Sibensko-kninska	0.00
Splitsko-dalmatinska	0.00
Istarska	0.10
Dubrovacko-neretvanska	0.00
City of Zagreb	2.70
Medimurska	2.66
Varazdinska	2.66
Koprivnicko-krizevacka	2.64
Krapinsko-zagorsk	0.30
Zagrebacka	2.64

42 Based on MoA Market Price Information 2016. System and confirmed with Producer organization. Deficit irrigation of soybean (Glycinemax. (L.) Merr.) based on monitoring of soil moisture, in sub-humid area of eastern Croatia. Romanian Agriculture Research, No. 33.

43 M. Markovic, M. Josipovic, M. Ravlic, A. Josipovic (2016). Deficit irrigation of soybean (Glycinemax. (L.) Merr.) based on monitoring of soil moisture, in sub-humid area of eastern Croatia.

FIGURE 11. Distribution of actual yield and yield gap

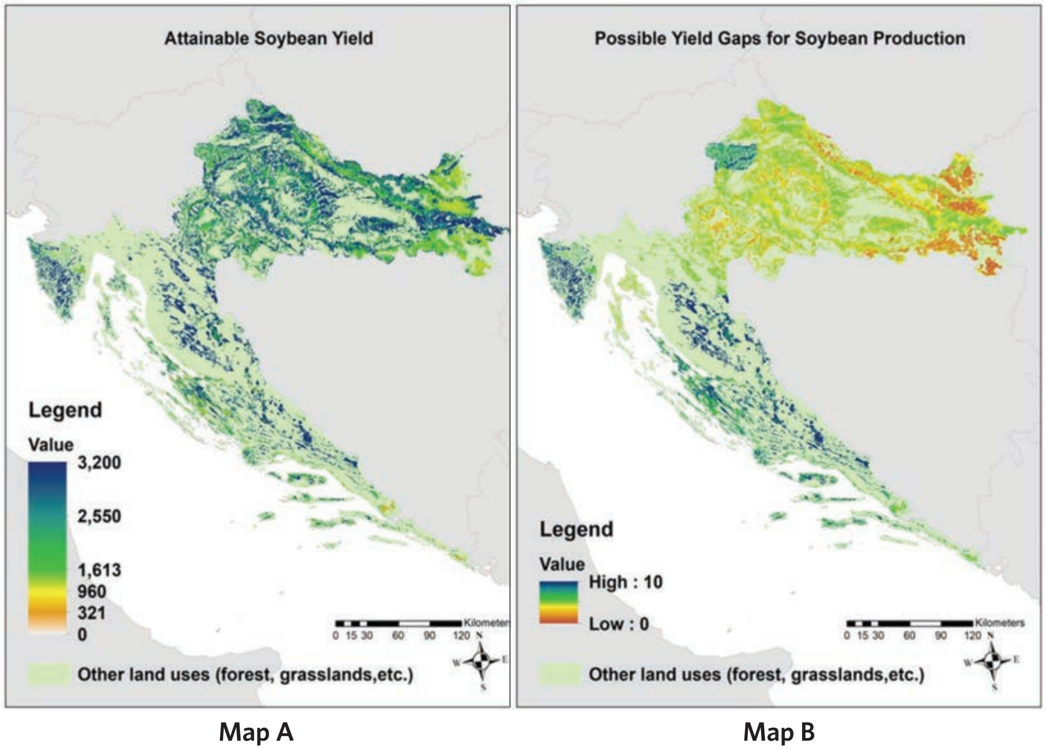
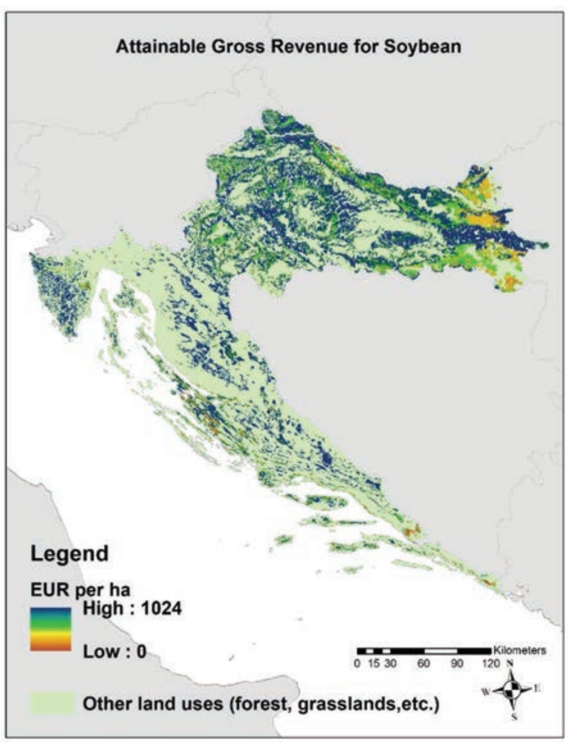


FIGURE 12. Estimated gross economic potential



4.3 Climate change preliminary impact assessment on crop suitability

Climate change alters the basics of productive ecosystems (e.g. temperature and rainfall), impacts natural resources (e.g. land and water availability) and agricultural and forest production. According to climate change projections, Croatia is expected to become hotter and drier—especially in the summer.[44] Climate change trends are projected to increase temperatures and decrease water availability across Croatia over the next century. Warming temperatures mean longer growing seasons and potentially increased spring soil temperature, but also more intense summer heat stress. These conditions may impact the annual number of days of active vegetation (temperature above 5°C) in the lowland parts of the country by mid-century. This may result in cultivation shifts depending on crops' needs for heat, light and water, impacting suitable areas for orchards, vineyards and olive groves. Areas currently unsuitable for agriculture may become more attractive. Furthermore, increased temperatures coupled with capability to provide adequate water (irrigation) could bring about increases in yields, especially for winter crops, which will be cultivated under mild winter conditions. Adverse impacts, i.e. drought risk, hail, flood, frost, etc., may impact production of key staple crops, winter wheat and maize.[45] Diminished surface runoff may also affect groundwater levels, affecting drinking water supplies as well as water availability for irrigation. Reduced precipitation and increasing heat trends for much of the country's agricultural areas are also expected to be impacted by increasing number of consecutive dry days[46] by 2050.

To demonstrate the applicability of the NAEZ spatial data platform to support climate change impact, a very preliminary assessment on the potential impact on land suitability for cherry was undertaken. This preliminary analysis applied projected change in temperature and precipitation in Croatia based on information available in the World Bank Climate Change portal[47] and based on Croatia's 7th Communication to the United National Climate Change Convention (UNFCCC) and applying the ensemble for 2030-2039 RCP 8.5. Key agroclimatic layers associated with cherry production were modified as follows: a projected annual increase of 1.91°C in temperature in the months of July and August, accumulated precipitation in May and June reduced by 2.25 mm and annual accumulated precipitation reduced by 1.25%. The results of the assessment indicate that changes in temperature and precipitation will likely decrease the suitability of cherry in the country. Decreases in the most suitable areas and in suitable areas will likely be reduced by 15.3 to 19.8% respectively (Table 11). Some areas in the mountainous regions showed increased suitability in response to lengthening of growing season which outweighs the risk of late frost. Suitability in areas in the central and eastern parts of the country likely will decrease due to warmer temperatures and reduced precipitation during critical period of the growing cycle (Figure 13). This is a very preliminary analysis and additional consideration of pests and other climate related factors and a gridded level analysis can help refine the assessment.

TABLE 11. Cherry suitability current conditions

	Cherry		
Suitability level	Current climate (ha)	Future climate (ha)	Percent change (%)
Most suitable (81-100%)	233,362	197,592	-15.3
Suitable (51-80%)	1,549,226	1,242,642	-19.8
Medium suitable (31-50%)	1,665,555	1,454,936	-12.6
Low suitable (11-30%)	1,132,721	1,314,362	+16.0
Marginal not suitable (1-10%)	681,886	1,053,222	+54.5

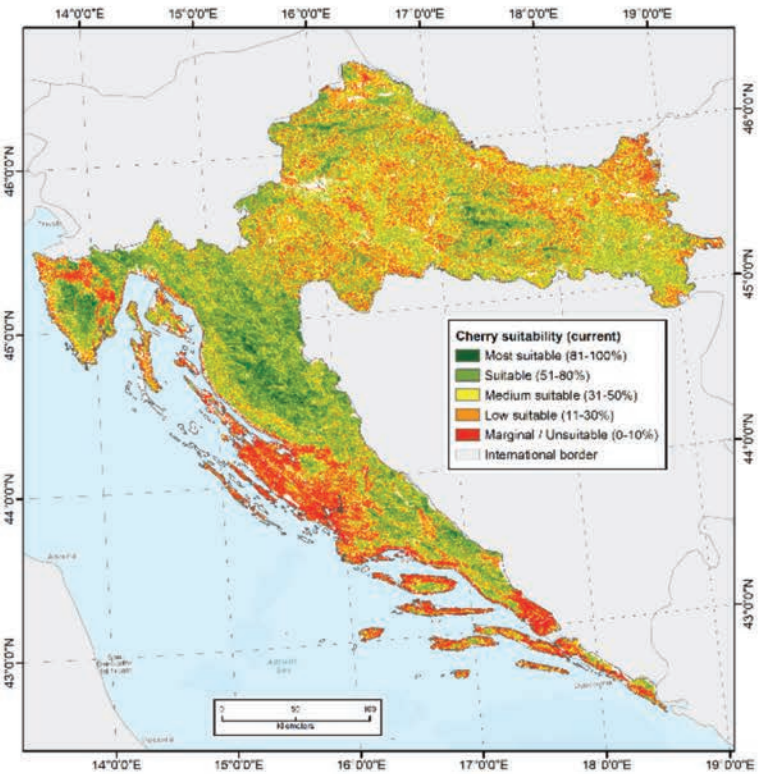
44 UNDP, 2008. A Climate for Change. Human Development Report – Croatia. http://klima.hr/razno/news/fastfacts.pdf

45 Croatia NC6, 2014.

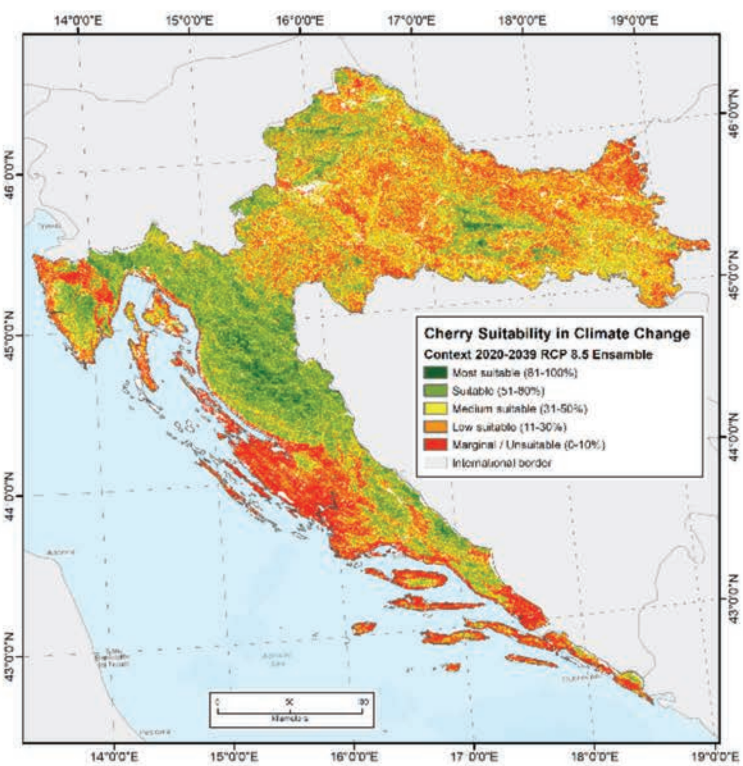
46 World Bank Group. Climate Change Knowledge Portal. Croatia Country Profile. Available at https://climateknowledgeportal.worldbank.org/country/croatia. Accessed March 2021.

47 https://climateknowledgeportal.worldbank.org/

FIGURE 13. Comparison current and climate change impact on cherry suitability in Croatia



Map A: Current conditions

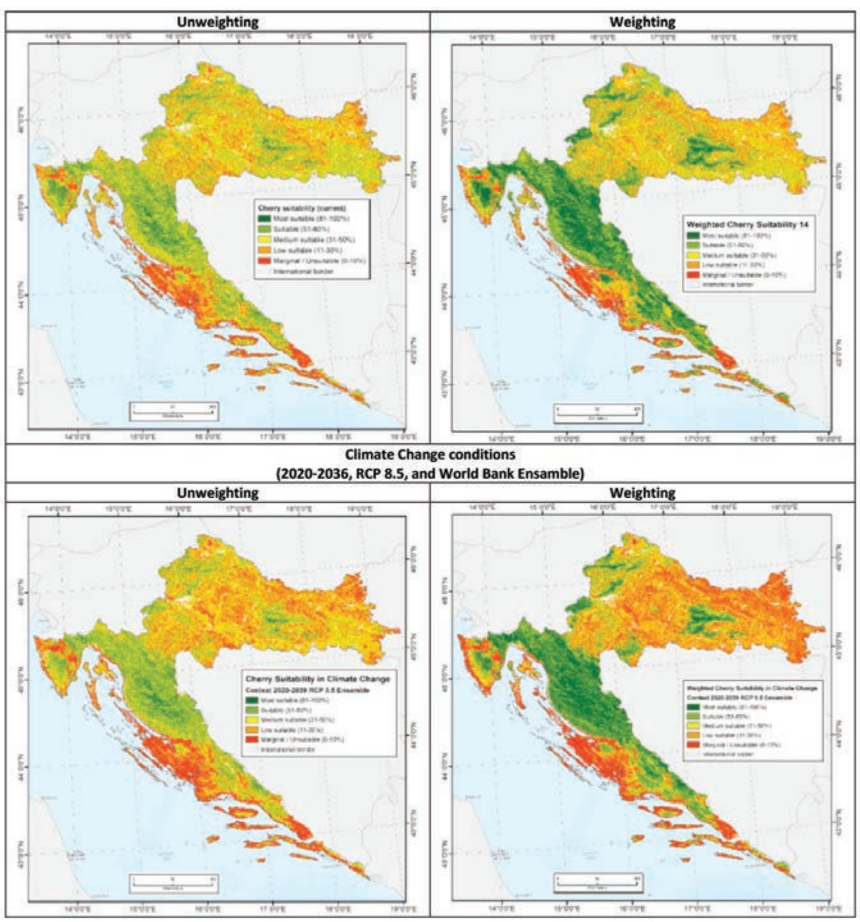


Map B: Climate change conditions based on RCP 8.5 Ensemble predictions

4.4 Technical improvements to the crop suitability analysis

During the process of preparing the training materials and in discussion with a local agronomist, a proposed improvement in the crop suitability analysis was tested to refine the original approach which gave all biophysical variables the same weight in a multi-criteria decision analysis. This approach was adapted using the analytical hierarchy process (AHP) developed by Saaty.[48] In this process pairwise comparisons between biophysical variables for crop suitability are carried out to estimate the overall weight of individual criteria. The comparison between criteria is made using a scale of 0.33 (much less important), 0.5 (slightly less important), 3 (much more important), 2 (slightly more important) and 1 (equally important). For example, when analyzing suitability for cherry growing in Croatia, a question could be whether soil type is (1, 2, 3, 0.5, 0.33) than rainfall in the summer; an answer of 3 indicates that soil type is much more important than rainfall in the summer. A questionnaire was generated, and the information was inputted into a pairwise matrix to determine the relative importance of weights for each criterion, before determining the final score. Relative coefficients were then estimated for each of the variables and integrated into the suitability analysis rather than giving all variables the same weight. This approach was applied to cherry suitability, generating better results as depicted in Figure 14 when compared to Figure 13. This approach was also presented during the training session under this pilot for apple suitability and the recommendation made was to use this approach in future assessments.

FIGURE 14. Comparison of cherry suitability multi-criteria weighted and unweighted assessments



48 Saaty, T.L. (1980). The analytical hierarchy process. McGraw-Hill, New York.

5 How Can Croatia Benefit from Using the NAEZ?

- **Regionalizing sustainable agriculture.** The underlying concept of the AEZ process is that each plant species requires a set of biophysical characteristics (soil, climate) to thrive, the further away the conditions in the land are from the needs of the crop, the least efficient, more intensive and costly the production system is. Extending the crop suitability analysis to other strategic crops can inform the preparation of a more regionalized strategy for sustainable agricultural production. The NAEZ platform can support that. At the onset of the pilot, 7 crops (cherry, corn, olives, soybean, apple, sunflower, grapes) were discussed. Through the development of the NAEZ, suitability assessments for cherry and soybean were carried out, also including apple during the practical training. Crop suitability assessments for other crops can be carried out using the existing platform by working with national agronomists to define crop-specific requirements, relevant weight of each biophysical variable and re-running the assessment with GIS experts. An agricultural crop mask using the Land Parcel Information System (LPIS/ARKOD) can be generated and compared to the crop suitability analysis for each crop to assess how actual production matches suitability. Additional work can link this information to specific crop models to identify regional crop yield potential from a biophysical lens, including the application of inputs (e.g. fertilizers). This information could be combined with market and infrastructure information to identify options for optimizing production and its consolidation within a given region. The platform enables the combination of the above information to support decisions on what regions, crops and production systems offer better alternatives in terms of economic, environmental (i.e. reduced use of fertilizer) and social factors.

- **Building an online soil and agronomy data platform.** Soil properties are critical for crop growth and yield and also influence the appropriate use of fertilizers and technification options. The fine spatial resolution (30m) of the soil information dataset developed by this Pilot is an important input towards developing this spatial data platform. For example, soil data (inorganic nitrogen, pH, organic matter, clay content, drainage, and moisture) together with mean soil temperature and rain (available from the DHMZ) during the cultivation period are important factors to guide appropriate crop fertilization. One immediate opportunity is to create an interactive online tool to support visualization of the soil property data at the national level or link it to the upcoming FaST v1.0 tool promoted by DG Agri so more refined national information is used instead of default regional information.[49] Other immediate application is the use of the soil organic carbon and nitrogen layers as proxies to identify areas suitable for organic farming following Radocaj et. al. (2021) approach.[50] This application can be very relevant for supporting organic agriculture measures in the country which will also contribute to the broader EGD objectives. Furthermore, creating additional layers of information at the national level on key soil micro-nutrients relevant to plants and measurements at variable depths can support, in the long term the building of a spatial agronomy data platform[51] as one option that can help strengthen agronomic advisory services and fertilizer recommendations at the producer level.

- **Understanding climate change impacts to agriculture is key to enhancing climate mainstreaming.** The main biophysical factor affecting future agricultural suitability is climate change. Information on local needs using national information on climate change impacts is needed to identify adequate adaptation strategies to increase resiliency of local production systems. Building this information base through the preparation of maps for suitable places for cultivation and crop distribution under a changing climate will support better targeting at the level of farm production adjustments such as diversification and intensification of crop and livestock production; changing land use and irrigation needs to define climate smart agriculture interventions. The NAEZ platform can be used to support this by building on the existing climatic layers to adjust them to reflect climate change projections in a process similar to the assessment done with cherry. This process needs to be coordinated closely with the Ministry of Economy and Sustainable Development and DHMZ to ensure that parameters are aligned and validated technically. The process can focus on selecting key crops of interest and applying a crop suitability analysis with the climate change condition layers (rain, temperature, aridity, LGP, frost free etc.). This analysis will indicate those crops that are more susceptible to climate change, the distribution of areas most affected for each crop and climatic conditions that contribute to these changes. With this information policy makers can start evaluating climate adaptation options such as different agronomic management, climate adapted varieties, irrigation, pest management etc. that could be supported to increase the resilience of the production systems. For example, increases in temperature during the most sensitive phenological period in cereal production could be addressed by shifts in sowing and/or cultivars. The assessment provides the basis for identifying feasible options, including mar-

49 Sample of this work at: https://www.clw.csiro.au/aclep/soilandlandscapegrid/ and https://fastplatform.eu/

50 https://www.sciencedirect.com/science/article/pii/S1470160X21000479

51 Sample of this work at: https://www.isda-africa.com/spatial-agronomy/

ket responses such as crop and flood insurance schemes, innovative investment opportunities, income diversification opportunities, that could be effective adaptation measures to climate change. It would also help understand the needs to support research and development for new crop varieties and hybrids or for autonomous varieties to support adaptation.

- **Linking the Biodiversity Strategy to future agriculture planning.** To optimize the environmentally sustainable use of land, it is essential to determine areas with agricultural potential from those that require resource conservation and/or protection (Altieri, 1992[52]). Recent literature has demonstrated the application of spatial planning to optimize benefits from sustainable agriculture while reducing biodiversity losses.[53] Using agricultural information from suitability and yield gap analysis combined with biodiversity information (species distribution layers i.e. terrestrial, aquatic, etc.) can help locate agricultural areas where there is a high potential for intensification but that are also biodiversity "hotspot" and where strategies should focus on conservation efforts rather than intensification. On the other hand, in areas where there is high potential for intensification and lower biodiversity pressures, strategies for sustainable intensification could be promoted. This type of assessment generates evidence-based information that is very relevant in light of the Biodiversity Strategy which goal is to increase by at least 10% the agricultural land managed as 'high-diversity landscapes' in EU countries. The NAEZ datasets can support this by (i) identifying areas that may have higher value for biodiversity and ecosystem services if restored from their current unsuitable agricultural use, (ii) identifying local and regional yield gaps (the difference between actual yields and potential yields) that are important indicators in where intensification and biodiversity conservation provide win-win situations and (iii) agricultural areas not currently used where biodiversity consideration for future agricultural development can be incorporated.

- **Opportunities for expansion to include water resources aspects.** Although, Croatia stands at the top of the water resources richness scale in Europe, it is significantly behind in terms of irrigated area globally. Yet weather conditions in eastern Croatia for example have shown a need for supplemental irrigation to safeguard against deficits of water during key phenological stages of crops (Sostaric, et al. 2013[54]). Historically droughts in Croatia have reduced yields by 20-92% depending on the intensity and duration. Sustainable irrigation and water management practices are relevant interventions to strengthen agricultural resilience. Irrigation is also important for high value crops to improve productivity, stabilize production and quality to meet growing market demands. Irrigation planning driven by agricultural needs and bio-physical conditions (climate, soil type, water quality and quantity) are paramount to ensure economically viable investments. Additional spatial information on water resources, complemented with existing soil and climatic data and crop-information can help identify the production potential that irrigated agriculture offers for key crops under current and climate change conditions. This information, combined with irrigation investment cost off and on-farm, can help better target irrigation strategies.

- **Risk management and measures.** Droughts are not covered by insurance according to the Financial Risk Management Diagnostic paper prepared by the STARS project. Droughts are considered very risky to cover as they are difficult to predict. Most farmers do not have ir-

52 Altieri, M.A. (1992). Agroecological foundations of alternative agriculture in California. Agriculture, Ecosystems and Environment. Vol 39 NOS. 1-2: 23-53.

53 Egli, L., Meyer, C., Scherber, C., Kreft, H. and Tscharntke, T. (2018). Winners and losers of national and global efforts to reconcile agricultural intensification and biodiversity conservation. Global change biology, 24(5), pp.2212-2228.

54 Sostaric, J., Markovic, M., Simunic, I., Josipovic, M. (2012). Irrigation – wish or necessity. In: Proceedings of 4th International Scientific Conference TEAM 2012. 17-19 October 2012, Slavonski Brod, Croatia, pp. 17-21.

rigation, so losses are difficult to avoid. Public investment in agroclimatic information systems and remote sensing can support the creation of risk maps and focus insurance support to those areas where insurance is the solution. This information will enable the delivery of more targeted incentives for producers to reduce risks in areas where risks are very frequent and very catastrophic. For example, in areas of frequent and severe droughts, farmers would need to invest in irrigation and in areas of severe floods, works would need to be done to reduce the impact of severe floods. Insurance would need to blend with incentives to reduce risks. The ongoing World Bank Helping Enterprises Access Liquidity (HEAL) project with Croatian Bank for Reconstruction and Development (HBOR's) Agricultural Credit Department has expressed an interest in the potential inclusion of climate risk management and financial instruments under the CAP Strategic Plan. The NAEZ spatial databases incorporates climate, soil and even flood risks maps to support agricultural risk assessments. The mapped climatic and agro-climatic zones, complemented with additional specific crop information (yields, areas etc.) and causes of losses, plus climate variability scenarios, can be used to develop pertinent indexes on agricultural risks to weather fluctuations and climate change.[55]

- **Beyond the farm.** Spatial information, coupled with production and market information, can help identify what crops offer greatest opportunities and the type of investments along the value chain that need to be made to strengthen linkages to markets. For example, identifying strategic location where processing and distribution infrastructures could be located. It could also support assessing the potential for co-product markets in relation to circular and bioeconomy strategies. For example, identification of available agricultural residues within economically viable perimeters to generate cost-effective integration into bioenergy or other bio-based industries. The available spatial data, complemented with additional information, can also inform strategies for food hubs based on production areas either under current production or potential production.

- **Other considerations.** Biophysical conditions (soil, climate, elevation, etc.) offer an indication of the agriculture land capability and suitability for certain crops. Socioeconomic situations, farm viability and stability are also important drivers in the decision on how land is used. Land use decisions are also influenced by policies. Providing the wrong incentives for crop production in areas where they are not economically viable will continue to incentivize farmers to grow them because of the income effects and not biophysical potential. Land suitability assessments need to be contextualized to cultural and socioeconomic aspects if successful transitions to sustainable production systems are to be realized.

55 C. Arce and E. Uribe. Managing vulnerability and boosting productivity in agricultural through weather risk mapping. 2015. Agricultural Global Practice Technical Assistance Paper. World Bank.

6 Conclusions and Next Steps

The NAEZ platform can support Croatia with identifying pathways towards green resilient and inclusive agriculture. In line with the recommendations from the NARDS, the NAEZ spatial information platform links natural resources: water, land, biodiversity, and climate to establish a biophysical baseline to guide agricultural spatial planning. NAEZ provides the framework for agricultural assessments to support diversification of the production structure towards greater sustainability and resilience to shocks. The NAEZ could also be used to identify current pressures on natural resources and help identify appropriate actions that can protect the country's rich agricultural biodiversity, including genetic resources. The agroclimatic information is one key component in NAEZ that can be further expanded to include climate change scenarios to identify specific impacts on key crops in the country and help identify appropriate climate change adaptation actions at the territorial level. As climate change will increase the frequency and intensity of extreme-climate events, agricultural risk instruments will be needed to complement adaptation strategies in the country. Currently only 7-8% of registered farmers in Croatia are insured, mostly medium and large producers. Environmental/climate data is key to generate better climate risk assessment and tailor financial and risk management solutions to reach smaller agri-food producers and MSMEs. Finally, spatial planning can support the development of land markets steering them towards more sustainable land use and management and inclusive agricultural development.

The geospatial integration of the diverse spatial data sets in the NAEZ platform as developed in Pilot 2 can support MoA deliver on national and international sustainability ambitions while also promoting the productivity and competitiveness of the agricultural sector. To realize this MoA will need to 1) continue strengthening its capacity for managing the NAEZ platform. Beyond the limited training offered at the conclusion of the pilot, additional training will likely be required to ensure that the internal capacity at the Ministry is fully developed; 2) MoA and HAPIH will need to validate the existing crop assessments and carry out new crop assessments for key crops and 3) the access to the platform and coordination with other relevant national institutions needs to be expanded. An interinstitutional dialogue to assess how the platform can be used to support policy decisions at the landscape level is highly recommended. As agriculture is part of the broader landscape and at the intersection of multiple sectors, a sustainable agriculture transformation requires that relevant actors be part of this discussion and decisions making.

TABLE 12. Summary of specific technical actions to support Croatia improve planning and enable the transformation of the sector

What we know	How can the NAEZ spatial platform support decisions
Productivity in Croatia is low	1) Assess how biophysical conditions impact productivity, and if crops are being produced in suitable areas. Work with national agronomists to define criteria and carry out additional crop suitability assessments for all relevant crops. 2) Compare existing yields to highest attainable yields to identify yield gaps and areas where there is a greater potential to increase productivity and for what crops. 3) Incorporate economic and market information to understand tradeoffs/synergies between economic returns and biophysical suitability. 4) Work with the Paying Agency to develop an agricultural crop mask to compare suitability, market and yield gaps to existing crop production and guide diversification strategies that are based on evidence. 5) Staff from MoA together with HAPIH, trained on the use of the platform, can lead this process in the country with the participation of agronomists.
Climate change vulnerability	1) Identify climate investments to safeguard agriculture. Together with DHMZ and Ministry of Economy and Sustainable Development define climate change scenarios and re-evaluate these in the agroclimatic layers to re-assess suitability for key crops to assess future impacts. 2) Climate risk insurance- The agroclimatic information is an important basis to analyze more in-depth climate risk impacts that can support develop and promote climate risk instruments in line with RDP measures. Engage financial institutions and disseminate the existing information and additional information that is needed to address key information needs that will help them tailor better financial risk instruments to reach out to larger pool of farmers and agri-food enterprises.
Land consolidation and intensification threaten the extensive cropland and agricultural mosaics which support biodiversity ecosystems	Use spatial analysis to identify sustainable intensification pathways: 1) Work with the Ministry of Economy and Sustainable Development to integrate biodiversity information. Compare existing production areas with biodiversity information to identify existing biodiversity hotspots– focus on this areas and type of agricultural interventions needed to minimize impacts– link this to agri-environmental/eco-schemes and other measures 2) Compare crop gap yield assessments to biodiversity information- identify areas with high potential for intensification but with high biodiversity value conservation purposes. Areas with high potential for intensification but lower biodiversity value for sustainable productive purposes.
Needs for optimal fertilizer and pesticide use	1) Use the digital soil map to identify areas suitable for organic production. The available soil organic carbon and nitrogen layers can be used as proxies to identify areas suitable for organic farming following Radocaj et. al (2021) approach. 2) Link the soil digital map to DG Agri FaST v1.0 app to ensure that national level data is used for decisions related to fertilizer use and farm management. 3) Compare the performance of different production systems based on different input levels and on existing biophysical conditions. This will need to be linked to crop model information following

TABLE 12. Summary of specific technical actions to support Croatia improve planning and enable the transformation of the sector

What we know	How can the NAEZ spatial platform support decisions
	Tian et.al 2014[56] or more simple approach of the Biomass and yield model from GAEZ FAO Model.[57] 4) Work with the Ministry of Economy and Sustainable Development and the Paying Agency to identify agricultural areas with current nutrient problems. Compare existing production against alternative production systems to identify potential actions that need to be promoted under the agri-environmental measures and eco-schemes.
Not much irrigation coverage	1) Link irrigation planning to agriculture assessment. Use crop suitability assessment under irrigated conditions and additional information on costing irrigation, market information to determine those crops that present the highest return on investment 2) Compare existing agricultural production areas to potentially irrigated areas.

Policy Recommendations

The application of the NAEZ platform can be used to inform and strengthen MoA's position in multiple fronts:

Short term:

- **Identify strategies to support sustainable productivity pathways.** The draft National Recovery and Resilience Plan (NRRP) provides a basis for key reforms needed to improve the use and management of natural resources, land consolidation and sustainable agriculture.
- **Support ongoing preparation of the current CAP operational program.** The use of the NAEZ platform can guide the preparation of the CAP programming and strengthen the evidence based for improved targeting. The platform can specifically support Croatia identify opportunities to promote measures on organic production, agroforestry/silvopastoral/silvoarable systems, agri-environmental practices for better soil management strategies related to greening objectives. It also provides a basis to start considering the EGD more objectively and to assess the actual contribution that Croatia can make towards meeting the EU ambitious goals. By generating evidence-base information, the MoA can strengthen its position in negotiating its CAP operational program with the EU Commission.
- **Develop regional adaptation strategies.** Incorporating different climate change scenarios into the NAEZ can support the formulation of regional agricultural adaptation strategies by identifying specific impacts to crops and regions and guiding climate investment needs.
- **Use of the existing platform to support the design of weather-risk management instruments for the agricultural sector** that are more targeted and accessible to more, mainly smaller, producers. Strong engagement with the financial sector will be needed to assess how the existing information can be used to support this process.

Medium Term:

- **Provide strategic guidance for irrigation investments in the country.** The NAEZ platform can be used for better targeting of irrigation investments in Croatia, with MoA objectively prioritizing those areas or crops that are viable from an environmental, social, and economic perspectives. The NAEZ platform, combined with economic and market information can support the identification of crops and areas where irrigation investments will make most sense.
- **Prepare the bioeconomy and circular economy strategy for Croatia.** The NAEZ platform is a framework to promote a participatory process

56 Tian, Z., Zhong, H., Sun, L., Fischer, G., van Velthuizen, H.T., & Liang, Z. (2014). *Improving performance of Agro-Ecological Zone (AEZ) modeling by cross-scale model coupling: An application to japonica rice production in Northeast China. Ecological Modelling* 290 155-164.

57 http://www.fao.org/fileadmin/user_upload/gaez/docs/GAEZ_Model_Documentation.pdf

bringing together stakeholders, civil society, and the public to identify key opportunities to promote sustainable actions. It is a tool that can be used in the formulation of a circular actions within the agricultural sector, contributing to the broader green agenda of the country.

Long term:

- **Promote the use of the NAEZ platform for local agricultural and rural development planning.** Develop the capacity of local authorities to use the platform for local planning, integrating local landscapes within sustainable development frameworks and strengthen local stakeholders' participation to help reconciliate competing interest between EU, national and local needs.

Annex 1: List of Intermediary Outputs

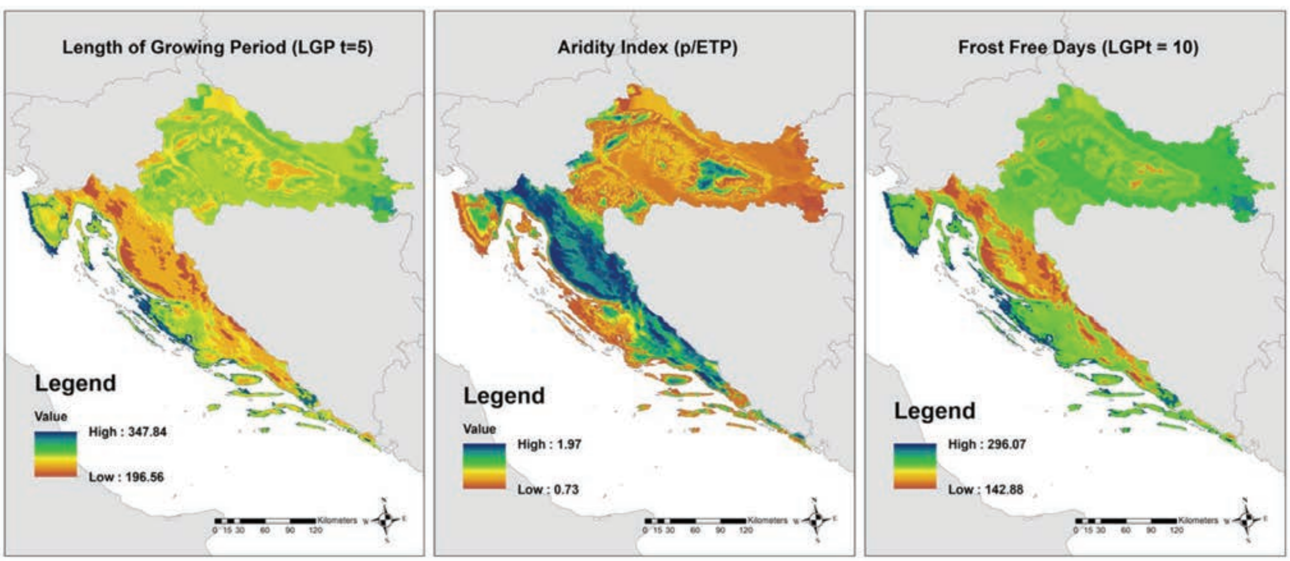
1. Climatic layers

TABLE A.1.1 List of agroclimatic related layers prepared at 30m resolution

#	Climate layers	Explanation
1	P_1988-2017	Precipitation (mm) averages between the years 1988 - 2017
2	Ta_1988-2017	Total Temperature (°) averages between the years 1988 - 2017
3	TaMax_1988-2017	Total Maximum Temperature (°) averages between the years 1988 - 2017
4	TaMin_1988-2017	Total Minimum Temperature (°) averages between the years 1988 - 2017
5	TaM1	Monthly, January, Temperature (°) averages between the years 1988 - 2017
6	TaM2	Monthly, February, Temperature (°) averages between the years 1988 - 2017
7	TaM3	Monthly, March, Temperature (°) averages between the years 1988 - 2017
8	TaM4	Monthly, April, Temperature (°) averages between the years 1988 - 2017
9	TaM5	Monthly, May, Temperature (°) averages between the years 1988 - 2017
10	TaM6	Monthly, June, Temperature (°) averages between the years 1988 - 2017
11	TaM7	Monthly, July, Temperature (°) averages between the years 1988 - 2017
12	TaM8	Monthly, August, Temperature (°) averages between the years 1988 - 2017
13	TaM9	Monthly, September, Temperature (°) averages between the years 1988 - 2017
14	TaM10	Monthly, October, Temperature (°) averages between the years 1988 - 2017
15	TaM11	Monthly, November, Temperature (°) averages between the years 1988 - 2017
16	TaM12	Monthly, December, Temperature (°) averages between the years 1988 - 2017
17	PM1	Monthly, January, Precipitation (mm) averages between the years 1988 - 2017
18	PM2	Monthly, February, Precipitation (mm) averages between the years 1988 - 2017
19	PM3	Monthly, March, Precipitation (mm) averages between the years 1988 - 2017
20	PM4	Monthly, April, Precipitation (mm) averages between the years 1988 - 2017
21	PM5	Monthly, May, Precipitation (mm) averages between the years 1988 - 2017
22	PM6	Monthly, June, Precipitation (mm) averages between the years 1988 - 2017
23	PM7	Monthly, July, Precipitation (mm) averages between the years 1988 - 2017
24	PM8	Monthly, August, Precipitation (mm) averages between the years 1988 - 2017
25	PM9	Monthly, September, Precipitation (mm) averages between the years 1988 - 2017
26	PM10	Monthly, October, Precipitation (mm) averages between the years 1988 - 2017
27	PM11	Monthly, November, Precipitation (mm) averages between the years 1988 - 2017
28	PM12	Monthly, December, Precipitation (mm) averages between the years 1988 - 2017
29	ETo_1988-2017	Total evapotranspiration (mm) averages between the years 1988 - 2017
30	EToM1	Monthly, January, Evapotranspiration (mm) averages between the years 1988 - 2017

31	EToM2	Monthly, February, Evapotranspiration (mm)averages between the years 1988 - 2017
32	EToM3	Monthly, March, Evapotranspiration (mm) averages between the years 1988 - 2017
33	EToM4	Monthly, April, Evapotranspiration (mm) averages between the years 1988 - 2017
34	EToM5	Monthly, May, Evapotranspiration (mm) averages between the years 1988 - 2017
35	EToM6	Monthly, June, Evapotranspiration (mm) averages between the years 1988 - 2017
36	EToM7	Monthly, July, Evapotranspiration (mm) averages between the years 1988 - 2017
37	EToM8	Monthly, August, Evapotranspiration (mm) averages between the years 1988 - 2017
38	EToM9	Monthly, September, Evapotranspiration (mm) averages between the years 1988 - 2017
39	EToM10	Monthly, October, Evapotranspiration (mm) averages between the years 1988 - 2017
40	EToM11	Monthly, November, Evapotranspiration (mm) averages between the years 1988 - 2017
41	EToM12	Monthly, December, Evapotranspiration (mm) averages between the years 1988 - 2017
42	FrFr	Frost Free Risk between the years 1988 - 2017. • Frost Risk (LGPt=10) (The frost-free period is approximated by the period during the year when mean daily temperatures are above 10°C (LGPt=10))
43	LGPt5	Length of growing period between the years 1988 - 2017. Counting the days which T> 5°C (and have continuity of at least five days)
44	Aridity Index	Aridity Index is calculated by dividing Precipitation to Evapotranspiration layers (p/ETO)

Key agroclimatic index maps



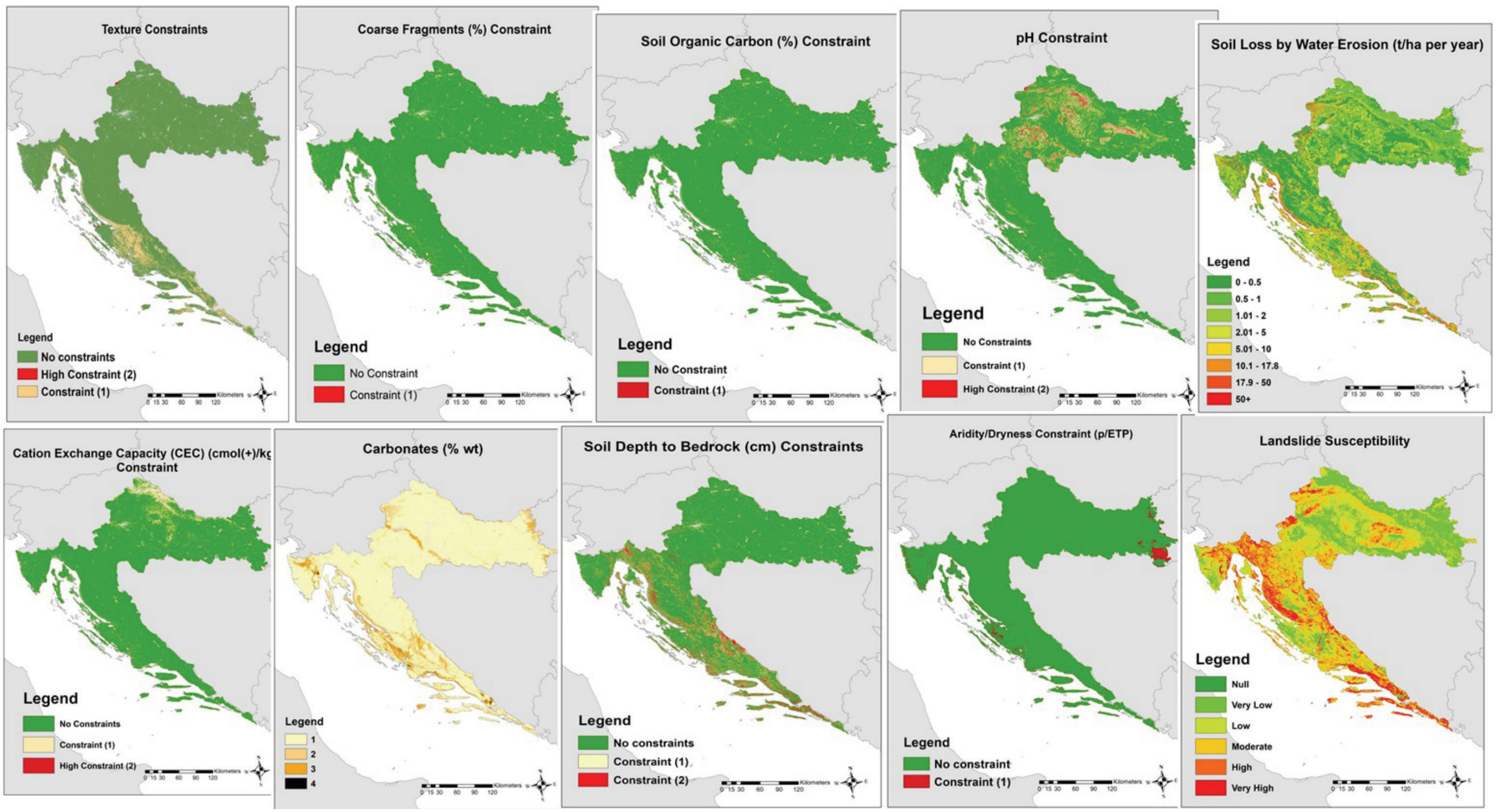
2. List of soil properties and attributes

Map code	Property	Measurement unit	Description
Soil Properties			
oC	Carbon, Organic	% wt	CMS analyte. Organic carbon is a measure of all organic forms of carbon in the soil, including organic carbon within minerals.
n_tot_ncs	Nitrogen, Total NCS	% wt	Total nitrogen is a measure of all organic and inorganic nitrogen, including that found in nitrogen minerals.
ca_mehlich3	Calcium, Mehlich3 Extractable	mg/kg	The calcium extracted by the Mehlich III solution.
k_mehlich3	Potassium, Mehlich3 Extractable	mg/kg	The potassium extracted by the Mehlich III solution.
mg_mehlich3	Magnesium, Mehlich3 Extractable	mg/kg	The magnesium extracted by the Mehlich III solution.
p_mehlich3	Phosphorus, Mehlich3 Extractable	mg/kg	The phosphorus extracted by the Mehlich III solution.
cec_sum	Cation Exchange Capacity, Summary	cmol(+)/kg	The effective cation exchange capacity is calculated by BASE_SUM+AL_KCl. It is not calculated if soluble salts are present. It is reported as meq per 100 grams on a <2 mm base. CMS derived value default.
ec_satp	Electrical Conductivity, Saturation Extract	dS/m	The electrical conductivity of the saturation extract is used to estimate the concentration of salts in a sample and provides inferences on cation concentration in solution and osmotic pressure. It is reported as mmhos per centimeter.
CaCO3	Carbonates	% wt	Carbonate in the < 2mm fraction is measured by CO_2 evolution after acid treatment. It is reported as gravimetric percent $CaCO_3$ on a <2 mm base, even though carbonates of Mg, Na, K, and Fe may be present and react with the acid.
ph_h2o	pH, 1:1 Soil-Water Suspension	(NA)	The pH, 1:1 soil-water suspension is the pH of a sample measured in distilled water at a 1:1 soil:solution ratio. If wider ratios increase the pH, salts are indicated.
ph_KCl	The pH, 1:1 soil-KCl suspension	(NA)	The pH, 1:1 soil-KCl suspension is the pH of a sample measured in 1.0N KCl at a 1:1 soil:solution ratio. If the pH in KCl < pH in water, Al^{+++} is indicated.
total_clay	Clay, Total	% wt	Total clay is the soil separate with <0.002 mm particle diameter. Clay size carbonate is included. Total clay is reported as a weight percent of the <2 mm fraction.
total_silt	Silt, Total	% wt	Total silt is the soil separate with 0.002 to 0.05 mm particle size. It is reported as a gravimetric percent on a <2 mm base.
total_sand	Sand, Total	% wt	Total sand is the soil separate with 0.05 to 2.0 mm particle diameter. It is reported a gravimetric percent on a <2 mm base. S prep.
wpg2	Coarse fragments	% wt	The weight fraction of particles with >2 mm diameter is reported as a gravimetric percent on a whole soil base.
db_od	Bulk Density, <2mm Fraction, Ovendry	g/cc	Bulk density, oven dry (105°C) is the weight per unit volume of the <2 mm fraction, with volume measured on oven dry (105°C) natural fabric (clods). It is reported as grams per cubic centimeter on a <2 mm base.
dbr	Depth to bedrock	cm	Depth to the R horizon or similar.
Soil Attributes			
wrb_rsg	Soil Clarification	World Reference Soil (RSG)	Predicted soil properties and taxonomy translated from Croatian to classification to RSG- 30 m resolution.
DEM_30	Digital Terrain Map	Elevation	Produced from AUTOCAD files at 30 m resolution.
Geo	Geological Map	Lithological composition	30 m resolution and re-classified to 54 classes.

3. Land cover, terrain, Natura 2000 - utilized

Map code	Property	Measurement unit	Description
Terrain			
clc18_hr	Land Cover	Classification	CORINE Land Cover Information for 2018. All features in original vector database were classified and digitised based on satellite images with 100 m positional accuracy and 25 ha minimum mapping unit into the standardized CLC nomenclature (44 CLC classes).
AgrMask	Agricultural mask	Classification	Lands classified as agricultural were extracted from clc18 to use as mask to calculate the area of suitability under agricultural lands.
Natura 2000_end 2019	Natura 2000	Sites	Official Natura 2000 sites - European ecological network of protected areas.
RamsarSites	Ramsar Sites	Sites	Ramsar Sites are wetlands considered to be of international importance.
WDPA2016	Global Protected Areas	Sites	There are currently over 2,200 Ramsar Sites around the world.
Soil Erosion	Soil erosion by water Land suceptibility to wind erosion	Sites	RUSEL 2015 by JRC.

4. Individual agricultural constraints



5. Summary of crop requirements for suitability analysis

TABLE A.1.2 Cherry crop requirements

		Very suitable	Mid suitable	Not suitable/Marginal/ Constraint
SOIL	Texture	Silty Clay (2)	Silt Loam (8)	Other textures
		Silty Clay Loam (3) Clay Loam (6)	Loam (9)	(1, 4, 7, 10, 11, 12)
	Depth	>1 m	0.6-1 m	<0.6 m
	SOC	2-33	1.5-2.0	<1.5
	CaCO3	<5	5-8	>8
	Soil type	Luvisol (9) Phaeozem (10) Eutric Cambisol (3) Chernozem (5)	Anthrosols (0) Cambisols (1) Dystric Cambisols (2) Leptic Cambisols (4) Fluvisols (6) Leptosols (8) Podzols (11) Regosols (12) Umbrisols (14)	Gleysols (7) Vertisols (15) Stagnosols (13)
	pH	6-7.2	5.5–6.0 & 7.2-7.5	<5.5 & >7.5
CLIMATE	Rainfall in May-Jun	200-229 mm	150-200 mm	<150 mm
	Accumulated annual rainfall	1000-1395 mm	733-1000 mm	–
	Maximum temperature	<28°	28-30°	>30°
	Average temperature	8°-11.5°	7.44°-8.5° & 11.5°-16°	>16°
	Frost risk (LGPt10)	180-296	143-180	<143
TERRAIN	Slope	5-15%	0-5%	>15%
	Aspect	S, SE, SW	W, E	N, NE, NW
	Curvature	Convex, slightly convex	Straight and semi-straight	Slightly concave and concave

Table A.1.3 Soybean crop requirements

		Suitable	%30-50 Midsuitable	Not suitable/Marginal
SOIL	Texture	Medium/Fine	Clay/Heavy clay	Sandy soils
	Coarse fragment	≤15	> 15%	100
	CEC	>10	10 to 2	2 to 0
	SOC	>1.3	0.8-1.3	<0.8
	CaCO3	0-20	20+	
	Soil type	Cambisols, Eutric Cambisols, Chernozems, Fluvisols, Luvisols, Phaeozems, Regosols	Dystric Cambisols, Vertisols	Gleyzols, Podzols
	pH range	6 and 7	5-6 & 7-8.2	<5 & >8.2
	Optimum pH	6.3-6.5		
WATER	Water requirements	May to July min 500 mm		
CLIMATE	Min temp	April =>10° The minimum temperature for effective growth of soybean crop is 10°C		
	Max temp	<40°		
	Temp range	20°-35°		
	Optimum temp	20°-30°		
	August drought risk	>0.65	0.5-0.65	<0.5
	Frost risk (LGPt10)	180-296	143-180	None of the soybean varieties are frost tolerant, and therefore they do not survive freezing winter conditions
	Rainfall	>500 mm/growing cycle 500-700 mm/year	143-180 mm	Jun, July, August <150 mm
OTHER	Slope	0-8%	8-15%	15>%

Annex 2: Pilot 2 Activities and Supporting Documentation

1. Chronology of Pilot Activities

Timeframe	Activity	Results
8 February 2019	Introductory meeting with high level officials from the Ministry of Agriculture to present the AEZ methodology	The Ministry officials got familiar with the AEZ methodology and its use to facilitate evidence based strategic planning and informed policies at national and sub-national levels.
1 April 2019	Meeting with representatives of the former Ministry of Environment and Energy Efficiency to present the AEZ methodology	The Ministry of Environment and Energy Efficiency (MEEE) (now Ministry of Economy and Sustainable Development) is the central administrative body for Croatia climate change activities and international commitments. As the functionality of the AEZ methodology go far beyond the agriculture, the idea was to make the MEEE aware of the initiative and exchange ideas how the tool can help them in meeting some of their international commitments.
5 April 2019	Meeting with representative of Paying Agency to get better insight into the GIS systems they use	The WB team got clear understanding of the GIS systems and maps that exist in the Agency (i.e. ARKOD and AGRINET).
19 July 2019	Meeting with DHMZ officials to exchange ideas on agro-meteorology and to explore areas for cooperation	The teams discussed the crop-weather modelling, agro-meteorology, GIS agro-climatic information and the AEZ. The DHMZ was very positive about the AEZ use in Croatia and ready to support its development with data supply and verification.
November – December 2019	Mapping of pilot project stakeholders	Institutions and agencies at national level dealing with any kind of GIS systems/agriculture were identified. In total 16 relevant institutions/agencies and academia were identified.
January - February 2020	Preparation of the survey	Semi-structured survey was prepared. The survey was composed of part 1: that covered general information about stakeholders and their role in AEZ as they see it and part 2: that covered technical issues related to the systems used, existing capacity, equipment, etc.
3 February 2020	Meeting with MultiOne	The purpose of the meeting was to assess the capacity of the local company to produce a digital soil map of Croatia.
5 February 2020	Meeting with DHMZ officials to exchange ideas on agro-climatic data	The meeting was held to agree on type of data needed for the development of the AEZ (i.e. temperature, precipitation).
5 February 2020	Meeting with MoA officials to present the Pilot project progress	Part of regular meetings to report progress.
28 February 2020	Meeting with EnvirometriX representative to commission a contract for quality control of digital soil map	The purpose of the meeting was to assess the availability of Tomislav Hengl to carry out Q&C. Tomislav Hengl is one of the world top soil experts.

Timeframe	Activity	Results
March – April 2020	Semi-structured survey conducting	The survey was sent to all mapped stakeholders. It was carried out in two rounds. In first round 13 stakeholders responded and in the second around the remaining 3. The survey results were used as the basis for the composition of a Technical Working Group to be established and training needs.
20 March 2020 (VC Erika Felix)	Meeting with MoA officials to report on progress	Due to the COVID-19 pandemic, Erika Felix joined the meeting via VC. The meeting was part of regular progress reporting.
20 May 2020	Concluding contract with MultiOne	The local company MultiOne was contracted to develop a digital soil map of Croatia in 30 m resolution.
June 2020	Concluding contract with Tomislav Hengl	Tomislav Hengl was contracted to carry out Q&C of the digital soil map and guide the development process.
3 August 2020	Meeting with MoA officials to present the Pilot project progress	Jela Bilandzija, representing the STARS RAS WB team was accompanied by Josip Krizan from MultiOne. Part of regular meetings to report progress.
7 September 2020	In agreement with the Ministry of Agriculture a request for DEM was sent to the State Geodetic Administration (DGU)	The DGU responded positively and provide DEM (DWG+DGN) fotogrametric restitution data 2017-2018 in 1,000+ sheets. The sheets had to be reclassified to be usable in production of digital soil map.
10 September 2020	Meeting with MoA officials to report on progress. Also, participants from the Croatian Agency for Agriculture and Food joined the meeting as they are in charge of soil data collection	The World Bank team informed the meeting on the progress achieved and next steps. The biggest challenge discussed at the meeting related to data fragmentation, different formats and resolutions. These make data overlap very difficult and required much more time than envisaged to reclassify data to a common format.
23 September 2020 (combination of in person and VC)	Technical Working Group (TWG) established and held its first meeting.	The TWG core mandate was to provide guidance and expert knowledge of Croatian agriculture, country needs, specifics and priorities about crops. At the meeting the process of developing the digital soil map and agro-climatic layers was presented. The TWG was positive about the presented results and did not have any major remark or comment.
27 October 2020	Delivery of digital soil map	Final digital soil map, WRB reclassified, resolution 30 m approved. The map is accompanied with a standalone report "Digital Soil Map Modelling". The report provides very thorough explanation of the entire process, step by step.
28 October 2020 (VC)	Meeting with DHMZ manager and technical experts	The purpose of the meeting was to present the final agro-climatic layers that incorporate comments received from the TWG. The DHMZ representatives were of the opinion that the presented layers reflect realistically the weather situation in Croatia and did not have any suggestions for changes. In total Croatia has 10 agro-climatic zones. The process of agro-climatic layers production is described in a standalone report "Climate Layers Modelling and Definition of Agro-Climatic Zones of Croatia".
27 January 2021	Meeting with MoA officials	Part of regular meetings to report progress. In addition, the next steps and timeline have been discussed to the project closing date that is 11 April.

Timeframe	Activity	Results
28 February 2021	Completion of Agro-ecological zonification	The agro-climatic layers, together with the digital soil map were the basis for assessment of natural constraints and delineation of agro-ecological zones. In total, Croatia has 13 agro-ecological zones. The process is described in standalone report "Assessment of Natural or Other Specific Constraints Affecting Agricultural Production & Identification of Agro-Ecologic Zones".
October 2020 – March 2021	Crop suitability analysis	In agreement with the MoA a crop suitability analysis was carried for soybean and cherry. Results of the suitability analysis are articulated in a standalone report "Assessment of Soybean Agricultural Suitability and Yield Potentials". Report for cherry suitability.
9 March 2021	Meeting with MoA officials to present draft outputs	The draft outputs were presented and discussed. No major comments or remarks received.
10 March	Submission of the draft Policy note in English	The draft Policy note was submitted to the MoA for comments.
25 March	MoA commenting the draft Policy Note	MoA's comments received.
23 March 2021	Submission of draft Policy note in Croatian	
12 March - 25 March	Training agenda submitted to the MoA	The MoA agreed with the proposed agenda.
March 2021	Design and delivery of the training program	The training program designed and delivered. The training was composed of (i) general part (GIS basics, crop requirements, suitability analysis); (ii) practical exercise – suitability analysis for apple; (iii) importance for policy makers . As part of this exercise, crop requirements in addition to soybean and cherry, were collected for apple and tomato.