Food and Agriculture Organization of the United Nations

REPORT OF PROCEEDINGS

Modernizing Global Agro-Ecological Zoning with new methods

24 March 2022

International Institute for Applied Systems Analysis

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Contents

Acknowledgements

The Geospatial Unit of the Land and Water Division (NSL) at Food and Agriculture Organization of United Nations (FAO) and the International Institute for Applied Systems Analysis (IIASA organized the second virtual consultation, on 24 March 2022, for the new version of the Global Agro-Ecological Zoning database (GAEZ v5).

The event was made possible thanks to the support of Environmental System Research Institute (ESRI), Asian Institute of Technology (AIT) and all the people that were able to take part in the discussions. The organizers would like to express their sincere gratitude towards the co-chair members, Honorable speakers who participated in the event and made it successful and representatives from various international, local, governmental and non-governmental organizations, universities, private sectors around the world who attended the webinar.

Abbreviations and acronyms

AEZ	Agro-Ecological Zones
AIT	Asian Institute of Technology
CMIP5	Coupled Model Inter-comparison Project Phase 5
CRU	Climate Research Unit
ESM	Earth System Model
ESRI	Environmental System Research Institute
FAO	Food and Agriculture Organization of the United Nations
GAEZ	Global Agro-Ecological Zones
GLC-Share	Global Land Cover Share
GLWD	Global Lakes and Wetlands Database
GSP	Global Soil Partnership
HWSD	Harmonized World Soil Database
IIASA	International Institute for Applied System Analysis
IPCC	Intergovernmental Panel on Climate Change
ISI-MIP	Inter-Sectoral Impact Model Inter-comparison Project
LCCS	Land Cover Classification System
LUT	Land Utilization Type
RCPs	Representative Concentration Pathways

Background

The Global Agro-Ecological Zoning version 4 (GAEZ v4), launched on 17 June 2021 uses well-established land evaluation principles to assess natural resources for finding suitable agricultural land utilization options. It is based on agro-climatic assessments, crop modelling, natural and human resources, crop statistics and water use at global scale. With the increasing complexity and intensity of environmental and social challenges an improved understanding of the biophysical determinants for agricultural management decisions including physical drivers of climate change is necessary.

The main strategic goal of GAEZ v5 is to make the outputs of the system available to national entities to support wise land use decision-making. To this end, supported by a GAEZ Partnership, GAEZ v5 will provide dynamically updated AEZ information, to meet local to global level AEZ users' needs.

To refine the overall GAEZ assessment, there was an initial consultation on the data used for GAEZ v5 in December 2021. Additional recommendations for updates, refinements and extensions of approaches and modules are listed in the Appendix 1-1 ("Recommendations for further GAEZ development") of the GAEZ v4 model documentation[1].

[1] Global Agro-Ecological Zones v4 – Model documentation available at https://www.fao.org/documents/card/en/c/cb4744en

Objectives

The objective of this consultation was to identify the methodological refinements and extensions to be addressed in the new GAEZ v5. The consultation looked at four main topics: i) crops, ii) water, iii) soil and iv) ecosystems functions.

Crops

GAEZ assesses over 50 different crops and uses the concept of Land Utilization Types (LUTs). An LUT describes cropping details beyond the crop type, including details on sub-varieties (e.g., wheat sub-varieties), applied management conditions (high, intermediate, low inputs use; traditional or advanced management) and water use (rain-fed, irrigation). Ground field validation of crop models and calibration with alternative modelling system has been carried out in selected national studies. Additional crops and LUTs not modelled in the current assessment should be identified for potential inclusion in the next global assessment. Approaches for systematic calibration of parameterizations and verification of outputs should be included where data availability permits.

Water

Efficient agronomic crop water management requires planning for optimal irrigation schedules including irrigation expansion for future scenarios. Agricultural investments require the capability to assess current and future water conditions in terms of quantity, quality and the sustainable potential of water available for irrigation. Future global and national assessments would greatly benefit and increase their utility by developing a tight link to water resources modelling and projections of water demand in different sectors. Water models[2] simulate surface- and groundwater resources, domestic, agriculture and industry water use, and environmental water needs. They track water flows over space and time.

In arid and semi-arid zones, water-conservation management practices are used to cope with marginal and unreliable rainfall. Assessment procedures which apply water balance calculations adapted and refined for dry environments have been developed and could readily be implemented in GAEZ v5.

Soil

Recent review of agro-edaphic procedures revealed update potentials with regard to three main themes, namely (i) soil characteristics ratings, (ii) available soil water capacity estimates, and (iii) the refinement of topsoil-subsoil attribute weighting schemes.

Ecosystems functions

Land has many important functions, however GAEZ currently cannot by itself compare the value of a potential crop provisioning service in a location with the value of potential alternative ecosystem services of the land. Multifunctional agriculture is increasingly discussed as a new paradigm for agriculture and rural development. It recognizes different ecosystem services of agricultural production systems including multiple pro-visioning services (e.g., food, feed, fiber, and energy crops), regulating services (e.g., erosion control) and cultural services (e.g., recreation, tourism). Agroecology becomes increasingly promoted for sustainable food systems transformations to jointly tackle food security,

[2] e.g., the open-source Community Water Model (CWatM)

climate change and enhance biodiversity through the multifunctional use of land resources, e.g., with a unit of land producing two or more crops (e.g., intercropping), crops and trees (e.g., agroforestry), or pastures for livestock browsing and selected tree crops. Integration of supplementary modules to quantify trade-offs and synergies among alternative ecosystem services within the GAEZ framework seems possible and desirable.

Openings

Douglas Muchoney, Head of Geospatial Unit, Land and Water Division, Food and Agriculture Organization of the United Nations (FAO)

Mr Douglas Muchoney opened the consultation by welcoming the distinguished colleagues and participants on the occasion of the second consultation for the development of the new Global Agro-Ecological Zoning Platform GAEZ v5. The recently launched GAEZ v4, developed by FAO in collaboration with IIASA, provides access to a further update of data and extension of the methodology compared to the previous version. GAEZ v4 provides access to > 300 000 global layers by theme, on:

- Land and water resources;
- Agro-climatic resources;
- Agro-climatic potential yield;
- Suitability and attainable yield;
- Actual yields and production, and
- Yield and production gaps.

GAEZ v4 is based on data available around 2010, and it is time now to provide an updated global database for Agro-Ecological Zoning. The new GAEZ v5 aims at: 1) providing updated information on future crop productivity under different climate scenarios, 2) becoming more participative in order to fulfill various needs and requirements, and 3) maximizing use of new technologies and information, in particular on geospatial, information and technologies.

Federica Chiozza, GIS and Remote sensing Expert, Geospatial Unit, Land and Water Division, Food and Agriculture Organization of the United Nations (FAO)

A brief review of the GAEZ v4 platform was presented, showing the products of the GAEZ platform and highlighting the transition from GAEZ v4 to GAEZ v5, objectives of which include: 1) fostering partnerships, collaborations and investments for sustainable and resilient landscapes and livelihoods, 2) improving data collection, quality and exchange based on the latest ICT, GIS/RS, AI/ML technological innovations, 3) enhancing inclusive and gender-responsive technical capacity with strong engagement from the youth, and 4) improving efficient development and use of AEZ for land management (in-country). The GAEZ platform is being improved by integrating it with several databases such as ECOCROP that gives access to a crop list, crop names, crop groups and crop requirements as well as Agro-MAPS which will provide information on crop land area, crop yield and crop production.

Introduction on refinements and updates of the Global Agro-Ecological Zoning methodology for GAEZ v5

Günther Fischer, Senior researcher, International Institute for Applied System Analysis (IIASA)

A brief presentation (Annex I) about the spatial datasets and methodology that were used in the current GAEZ v4 database was given, highlighting the modules of GAEZ. The recommendations for further GAEZ v5 development were illustrated which included: 1) Crop datasets: expanding the number of LUTs and verification/calibration of crop/LUT parameterization, 2) Water data: develop a tight link to water resources modelling and water use assessments, 3) Soil data: agro-edaphic evaluation improvement, inclusion of water conservation practices in dry region, and 4) Multifunctional approach to ecosystem services according to the GAEZ v4 model documentation; strengthen the capabilities in AEZ to assess alternative ecosystem functions/benefits. Methodology improvements and extensions include developing a close link with water resources modelling, agro-edaphic evaluation and strengthening capacities in AEZ to assess alternative ecosystem function/benefits.

Crops

Moderated by Gianluca Franceschini, Senior Land Resources Information Expert, Land and Water Division, Food and Agriculture Organization of the United Nations (FAO)

A brief presentation on the importance of modelling crops yield to the agro-ecological zoning methodology was given, citing the significance of LUT and input levels. GAEZ models potential productivity and suitable land for 52 crops grouped under cereals, roots, sugar crops, pulses, vegetables, fruits, oil crops, bioenergy, fodder, industrial crops and narcotics and stimulants. Crop varieties, crop parameters, agro-climatic constraints and crop constraints on soil and terrain were also presented. The objective of this discussion was to review the methodological approach related to crops, in order to verify/calibrate crop/LUT parameterization and expanding the number of LUT.

During the discussion, it was suggested to add to the modelling a number of additional crops not included in the current GAEZ , in particular strengthening the number of available perennial crops (e.g. avocado, mango, citrus), geographically-important cash crops (e.g. saffron, ginger) and other crops important for non-edible uses (e.g. bamboo). It was also discussed alternative ways to aggregate and present crops-specific results: by “umbrella” crops (i.e. a basket of pre-defined crops that shows the highest per-pixel suitability to compare the performance of individual crops with the maximum suitability), by calories produced, by degree of vulnerability to environmental and climatic risk, by their contribution to national import/export, or by carbon sink. Other crop-specific functions that could be added to GAEZ included; development of fast suitability index with a minimum set of crop information, best irrigation method suitability and a better linkage with ECOCROP. Other ways of validating and calibrating outputs to be added to GAEZ were also discussed, more focused on the use of machine learning.

Enhance GAEZ v5 utility by developing a tight link to water modelling

Moderated by Sylvia Tramberend, Research Scholar, International Institute for Applied System Analysis (IIASA)

A review of water data and modelling in GAEZ v4 was given highlighting the fact that suitability of crops under irrigated conditions in terms of agronomic requirements and prevailing climate and soil/terrain resources are assessed. GAEZ v4 uses a spatial layer of 'areas equipped for irrigation' released in 2013, which may already be outdated. However, there is no assessment about the actual availability, reliability, and quality of irrigation water supply in the areas of interest.

Foreseen GAEZ improvements were discussed such as; Future global and national assessments would greatly benefit and increase their utility by tapping into information as to where water can be obtained, during which months and in what quantities and qualities; This is particular relevant for planning of irrigation expansion under climate change, which requires knowing both, i) where does irrigation improve agricultural productivity (already calculated in GAEZ v4) and ii) where will water be available under climate change and future socio-economic development trends (to be further developed in GAEZ v5). This could be achieved by using Water Models, which simulate hydrology, i.e. track water availability and human water use over space and time, and should be tightly linked to GAEZ v5.

Main conclusions and recommendations were;

- Assessing water availability for potential irrigated crop production systems is very useful, foremost in view of climate change assessments and irrigation planning;
- An update of the spatial layer for current 'areas equipped for irrigation' is desirable. FAO is currently exploring the use of Remote Sensing products for a delineation of irrigated areas (case study Malawi);
- Climate hazards due to extreme events (dry spells, flooding) and increasing climatic variability are of particular importance in the climate negotiations of the UN Conference of Parties, which could greatly benefit from GAEZ output in this regard;
- Livestock and fodder systems are a critical for developing sustainable agricultural systems. This requires information about sustainable fodder crops and livestock water use/needs, and
- Funding potentials for above activities were discussed. Climate Investment Funds should be explored. FAO Uganda has a priority theme of developing small-scale irrigation systems.

Soil component

Matieu Henry, Technical Officer and Yusuf Yigini, Land and water officer, Land and Water Division, Food and Agriculture Organization of the United Nations (FAO)

A brief overview of soil and terrain data used in GAEZ v4 was presented. Examples of new global soil data and new national data were emphasized. There is a possibility of updating the Harmonized World Soil Database because HWSD v1.2 is partly based on dated soil information (DSMW) at small scale in large regions (North America, Australia, West Africa, parts of SE Asia), HWSD v1.2 uses WISE v1.2 for soil property estimations which has been improved since then (WISE30arcsec) and HWSD v1.2 would benefit from using WRB as a soil classification (as done in Soil Atlas of Africa (JRC). This activity could best be undertaken by ISRIC under a project arrangement. An alternative global soil database: SoilGrids250m that uses Digital Soil Mapping (DSM) approaches and draws on a substantial number of soil profile observations also in North America, Australia and Africa (AfSIS) including its advantages and disadvantaged were discussed.

Three options were envisaged before and during the meeting: 1) Replace the present HWSD soil layer with SoilGrids250m (ISRIC), a soil property database with high resolution. This option was not retained because its focus is exclusively on a small number of soil properties aimed at environmental assessment, 2) Building up a global soil property database based on national contributions (GSP). This may well be the best long-term solution, but cannot be achieved in the next ten years, and 3) Improving the present HWSD database (FAO/IIASA) with new datasets that are readily available or that can be prepared in a reasonable timeframe (less than one year).

Global land degradation assessments were presented, but were thought to be mainly useful to serve as part of the exclusion layers. The soil erosion dataset recently prepared at JRC would be considered as a replacement for the GAEZ v4 approach based on slope % and rainfall intensity.

In conclusion:

- 16 soil properties will need to be updated;
- Some important input parameters e.g. slope for attribution soil properties could be added to GAEZ;
- A table of global soil data to be shared and an update of HWSD for GAEZ were proposed;
- Potential national datasets will be added;
- Better consideration of soil layers e.g. seven layers identified by ISRIC WISE 30 arc-sec at 20 cm, and
- Pre-processing and connecting all layers to HWSD index raster (HWSD for GAEZ v5).

Strengthen the capabilities in GAEZ v5 to assess alternative ecosystem functions/benefits

Moderated by Günther Fischer, Senior researcher, International Institute for Applied System Analysis (IIASA)

The purpose of Exclusion Layer in GAEZ v4 was noted. GAEZ outputs emphasize the suitability of land for crop production. Planning for more and better food supplies, produced with fewer resources, causing less environmental impacts and safeguarding biodiversity, will have to continue with high priority in the next decades. Elements and compilation of GAEZ v4 exclusion layers were summarized. The 'exclusion' layer in GAEZ v4 distinguishes six classes at 30 arc-seconds resolution.

Recommendations from the discussion for further GAEZ v5 development included:

- GAEZ applies an 'exclusion' layer to highlight land with a protection status or with recognized biodiversity value.
- However, GAEZ currently cannot by itself compare the value of a crop provisioning service in a location with the value of potential alternative ecosystem services of the land.
- Integration of additional datasets or supplementary modules to quantify trade-offs and synergies among alternative ecosystem services within the GAEZ framework seems possible and desirable.
- It is recommended to produce an overview of available models and data sources and to develop a strategy for incorporating new modules/develop links to ecosystem valuation approaches that would operate consistently using the spatial data available in the AEZ land resources inventory.
- What is currently missing in GAEZ for appreciating most important alternative ecosystem functions/services? Where do you see biggest need to extend methodology?

Future perspectives and closing remarks

Matieu Henry, Technical Officer, Land and Water Division, Food and Agriculture Organization of the United Nations (FAO)

A total of 18 organizations participated in the consultation. The consultation was closed with the emphasis of the next steps:

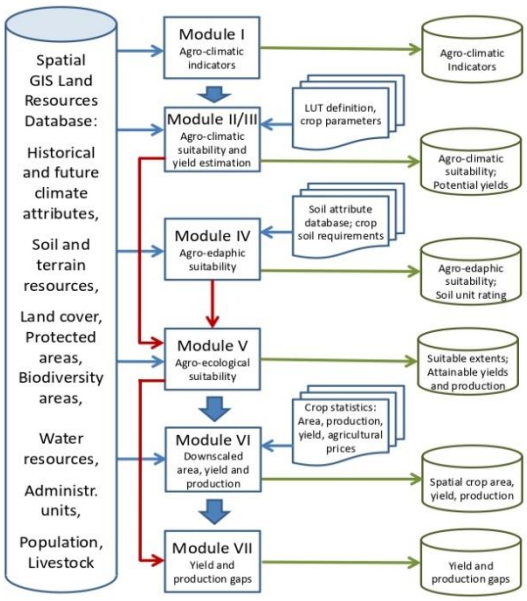
- the results of this consultation (proceedings and presentations) are distributed and shared with all participants;
- data collection and processing are ongoing for the input global layers for GAEZ v5;
- first data to be processed for Module 1 will take place in June 2022;
- GAEZ v5 will be integrated with additional datasets on crop requirements and crop statistics (ECOCROP, Agro-MAPS).

Annex I

Global Agro-Ecological Zoning (GAEZ)

- A multidisciplinary and collaborative framework for e.g. land use planning, sustainable land management, food policies and climate change impact assessment;
- In support to resilient agriculture, ecosystems and livelihoods to climate change and food crisis;
- Provides interactive and dynamic web application to report on the current state and trends of agricultural production and crop suitability;
- Enables public access to data and information, becoming a gateway to global, regional and local geospatial and tabular information on agricultural resources and potential

Introduction to GAEZ v4 – Point of Departure



Module I: Climate data analysis and compilation of general agro-climatic indicators for historical, baseline and future climates.

Module II: Crop-specific agro-climatic assessment and water-limited biomass/yield calculation.

Module III: Yield-reductions due to the impacts of agro-climatic risks and constraints of workability, pests and diseases.

Module IV: Crop specific edaphic assessment and yield reductions due to soil and terrain limitations.

Module V: Integration of results from Modules I-IV into crop-specific grid-cell databases for mapping the agro-ecological suitability, attainable yields and potential production.

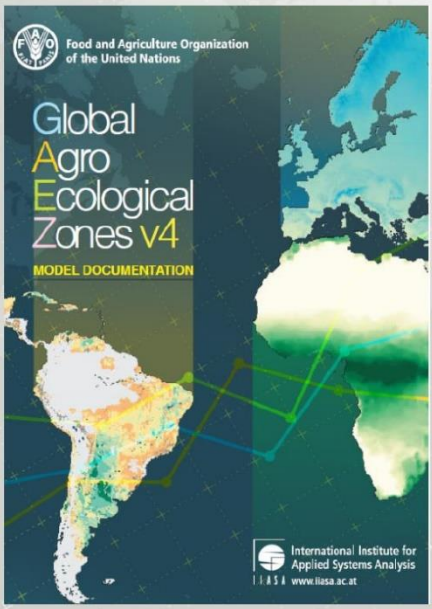
Module VI: Joint attribution of area, yield and production of all statistically recorded crops to the rain-fed and irrigated croplands.

Module VII: Quantification of yield gaps by comparing potential rain-fed and irrigated yields with yields of downscaled statistical production.

Data and Methods used in GAEZ v4

For further information on data and methods used in GAEZ v4, see details provided in the v4 Model Documentation available at:

https://gaez.fao.org/



Recommendations for further GAEZ v5 development

Methodology improvements and extension

The GAEZ v4 Model Documentation and subsequent consultations have identified desirable improvements and extensions of methodology and data for consideration in GAEZ v5:

- Expand the number of Land Utilization Types
- Verification/Calibration of crop/LUT parameterization
- Develop a tight link to water resources modelling, water use assessments, irrigation development planning
- Agro-edaphic evaluation improvement
- The inclusion of water conservation practices in dry regions
- Strengthen the capabilities in AEZ to assess alternative ecosystem functions/benefits

I. CROPS

II. WATER

III. SOIL

IV. ECOSYSTEM FUNCTIONS

Recommendations for further GAEZ v5 development

I. CROPS

- **Expand the number of Land Utilization Types:**

Additional crops and LUTs not modelled in the current assessment should be identified for potential inclusion in the next global assessment, e.g. LUTs specifically parameterized in the context of national and regional AEZ studies. Examples include food crops (cashew, castor bean, lentil, mustard seed, black pepper, sesame seed, mango), fodder crops (Brachiaria) and various biofuel feedstocks (Solaris tobacco, biomass sorghum, energy cane, Brassica carinata, Camelina, Macauba).

- **Verification/Calibration of crop/LUT parameterization:**

Ground field validation of AEZ crop models and calibration with eco-physiological and genetic paramters generated through coupling with alternative site specific modelling analysis has been carried out in selected national studies. Approaches for systematic verification of outputs should be included where data availability permits.

Recommendations for further GAEZ v5 development

II. WATER

- **Develop a tight link to water resources modelling and water use assessments, e.g., for irrigation development planning:**

GAEZ v4 has assessed the suitability of crops under irrigated conditions in terms of agronomic requirements and prevailing climate and soil/terrain resources, but has not assessed the actual availability, reliability and quality of irrigation water supply in these areas. Future global and national assessments would greatly benefit and increase their utility by tapping into information as to where water can be obtained, during which months and in what quantities and qualities.

For instance, IIASA has developed a new Community Water Model (CWatM), which can simulate hydrology both globally and regionally at different resolutions from 30 arc-minutes to 30 arc-seconds at daily time steps. CWatM is open source in the Python programming environment and includes general surface and groundwater hydrological processes but also takes into account human activities, such as water use and reservoir regulation.

Recommendations for further GAEZ v5 development

III. SOIL

- **Agro-edaphic evaluation improvement:**

Recent review of current agro-edaphic procedures identified update potentials with regard to three main themes, namely (i) soil characteristics ratings, (ii) available soil water capacity estimates, and (iii) the refinement of topsoil-subsoil attribute weighting algorithms. A methodology to address these opportunities for improvement has been developed and could be applied promptly.

- **The inclusion of water conservation practices in dry regions:**

In arid and semi-arid zones, water-conservation management practices are used to cope with marginal and unreliable rainfall. These zones typically receive annual rainfall between 300 and 600 mm and cover an area with total extent of 3.2 billion hectares. Assessment procedures which apply water balance calculations adapted and refined for dry environments have been developed and could readily be implemented.

Recommendations for further GAEZ v5 development

IV. MULTIFUNCTIONAL APPROACH TO ECOSYSTEM SERVICES

- **Strengthen the capabilities in AEZ to assess alternative ecosystem functions/benefits:**

Land has many important functions. GAEZ outputs emphasize the suitability of land for crop production. The need to plan for more and better food supplies, from less resources and with less environmental impacts, will have to continue with high priority in the next decades. Current GAEZ applies an 'exclusion' layer to highlight land with a protection status or with recognized biodiversity value. However, GAEZ currently cannot by itself compare the value of a crop provisioning service in a location with the value of potential alternative ecosystem services of the land.

It is recommended to develop a strategy for incorporating new modules/develop links to ecosystem valuation approaches that would operate consistently using the spatial data available in the AEZ land resources inventory.

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The Global Agro-Ecological Zoning version 4 (GAEZv4), launched on 17 June 2021, uses well established land evaluation principles to assess natural resources for finding suitable agricultural land utilization options. It is based on agro-climatic assessments, models, natural and human resources, crop statistics and water use at global scale. With the increasing complexity and intensity of environmental and social challenges an improved understanding of the physical drivers of climate change is necessary. Consequently, the identification of methodological refinements and extensions is intended for the further development of GAEZ.

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