Catalogue |

GEOSPATIAL TOOLS AND APPLICATIONS FOR CLIMATE INVESTMENTS

Prepared by IFAD's Change, Delivery and Innovation Unit (CDI) for the ShareFair event at COP26

IFAD INNOVATION

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Catalogue of geospatial tools and applications for climate investments

This catalogue was prepared by IFAD's Change, Delivery and Innovation Unit (CDI) for the ShareFair event at COP26 on 9 November 2021.

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List of acronyms

APIU	Agricultural Projects Implementation Unit
ARIS	Community Development and Investment Agency
ASHA	Adaptation for Smallholders in Hilly Areas Project
CDI	Change, Delivery and Innovation Unit in IFAD
CHIRPS	Climate Hazard Group InfraRed Precipitation with Station data
COP26	26th Conference of the Parties – the United Nations climate change conference
EO4SD	Earth Observation for Sustainable Development
ESA	European Space Agency
FAO	Food and Agriculture Organization of the United Nations
GAEZv4	Global Agro-Ecological Zoning version 4
GIS	geographic information systems
GPS	global positioning system
ICRAF	World Agroforestry Centre
IFAD	International Fund for Agricultural Development
M&E	monitoring and evaluation
NASA	National Aeronautics and Space Administration
NDVI	Normalized Difference Vegetation Index
SEPAL	System for Earth Observation Data Access, Processing and Analysis for Land Monitoring
WFP	World Food Programme

Table of contents

A. INTRODUCTION

Climate change poses unprecedented challenges for humanity. Agriculture is one of the most affected sectors as heat waves, floods, droughts, storms and other natural disasters linked to climate and weather extremes affect millions of small producers around the world. For development organizations, such as IFAD, it is therefore **vital to know how and where climate change is affecting smallholder farming** in order to pursue effective interventions. Geospatial technology is a key element of this – and IFAD uses **geospatial tools to help map, assess and target its climate-related investments.**

This catalogue features innovative geospatial tools and real life case studies from IFAD's operations, to give a flavour of how and where IFAD uses such technology. It is a side product of the ShareFair – a virtual ideas marketplace – that IFAD organized in November 2021 as part of the COP26 climate summit in Glasgow.

Figure 1. This catalogue features IFAD activities in 22 countries.

The catalogue presents **16 geospatial tools and applications for climate investments** that were presented at the ShareFair, and is aimed at designers, implementers and evaluators of projects financed by development finance institutions. It features:

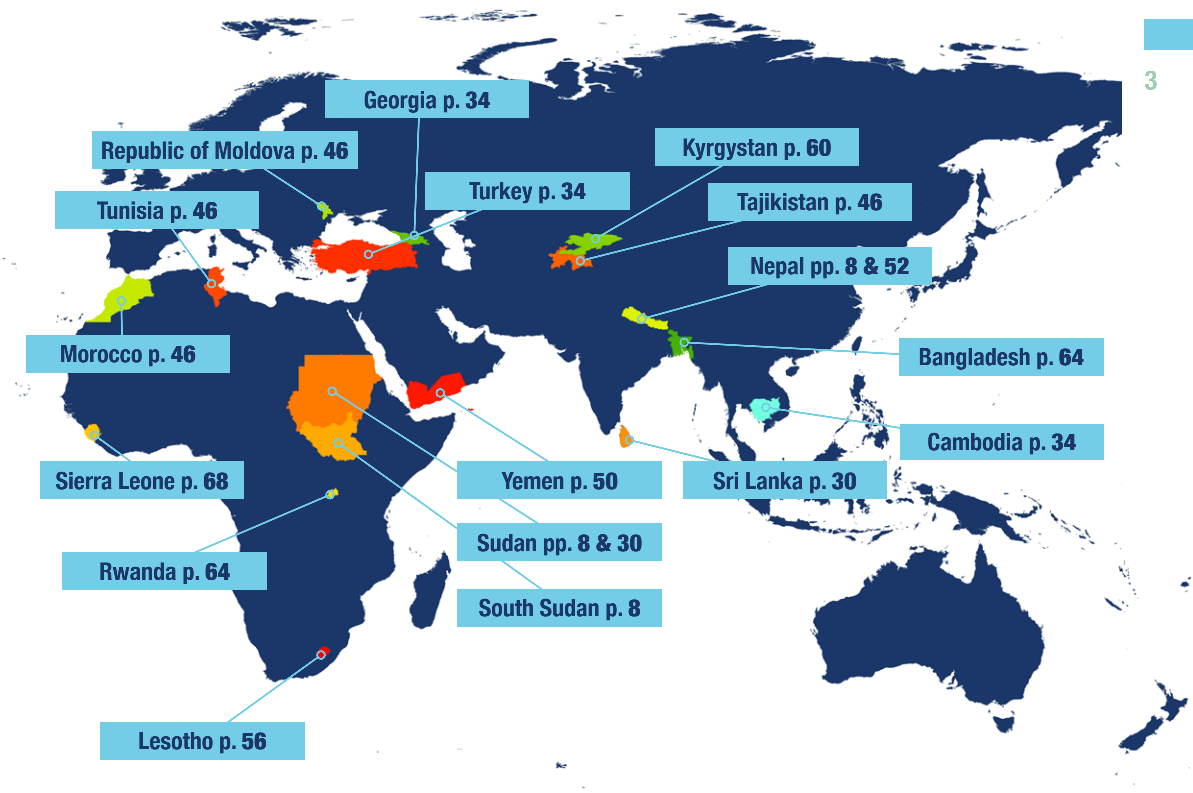
- **Eight tools and approaches** that can be applied to inform the formulation of projects, monitor their progress, and assess their impacts; and
- **Eight related case studies** showcasing how geospatial technology is applied in IFAD-funded operations.

Under each catalogue entry, you can:

- Read **short descriptions** (written for non-GIS-experts) of the tools and case studies;
- Discover interesting **maps and visuals**;
- Find more information in the **web-links** provided; and
- If you have more questions, find the **contact details** of the experts involved.

IFAD relies on the geospatial data and expertise of other organizations to perform its analyses. The catalogue features the work of a number of these **important partners**, most notably fellow Rome-based agencies the Food and Agriculture Organization of the United Nations (FAO) and the World Food Programme (WFP), and the European Space Agency (ESA).

This catalogue promotes a number of geospatial tools under FAO's Hand-in-Hand Initiative that can support the design and implementation of large agricultural programmes such as of IFAD.



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B. SIX WAYS TO USE GIS FOR CLIMATE INVESTMENTS

Geospatial analysis can be applied in all project stages: (i) to inform the design; (ii) to monitor progress during implementation; (iii) and to assess impacts at completion.

1. **Targeting climate-vulnerable areas**. When designing a new project with a government, two important questions are: (i) who the project should benefit; and (ii) where, geographically, the project should be situated. GIS tools can help with this: some tools give easy access to complex data; other projects benefit from detailed vulnerability assessments to assess where climate change is likely to create the most serious problems and where interventions are most urgently needed.

2. **Planning adaptation measures**. GIS can be used to select the best-suited interventions to help communities adapt to climate change – for example, to determine the extent and location of measures such as afforestation or landslide protection. A number of IFAD projects develop community-level adaptation plans that combine community knowledge and GIS assessments.

3. **Monitoring climate investments**. Systematic geo-referencing allows development organizations to monitor progress, precisely measure the geographic extent of an activity, and, most importantly, use the data for impact analyses during and after project completion. IFAD has ambitions to systematically integrate GIS in monitoring and evaluation of its projects. Over 60 IFAD-funded projects geo-tag their activities to various degrees.

4. **Securing land tenure as a foundation for adaptation**. Farmers who do not have secure tenure of the land where they grow crops or keep livestock may be unwilling to invest in it. So improving their tenure security is essential. A new learning programme by IFAD and the Food and Agriculture Organization of the United Nations (FAO) provides participants with techniques and tools on how to select the most appropriate technologies to record land in rural development projects.

5. **Assessing impacts of climate investments**. Development organizations need to find out the impacts that a given project has had on helping farmers adapt to climate change. IFAD analyses to what extent its investments make the rural poor more climate-resilient by surveying households in the project area and extracting information from geospatial datasets to compare households that benefited from a project with households that have not received support.

6. **Partnering with organizations**. IFAD collaborates with institutions that use state-of-the-art geospatial analysis and information. The Fund has long-standing partnerships with, for example, fellow Rome-based agencies FAO and the World Food Programme (WFP), and other organizations like the European Space Agency (ESA).

C. TOOLS AND APPROACHES

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Targeting vulnerable areas

Geospatial climate vulnerability mapping tool

Climate change is one of the most pressing issues of our times, but it can be difficult, expensive and time-consuming to target investments so that they reach the people who are most likely to feel its impacts. Geospatial tools can help overcome this problem. The IFAD GeoAdapt method combines carefully chosen indicators into a compound index that shows the vulnerability of people in different areas in a country. It creates maps that quickly show which areas should be the focus of interventions.

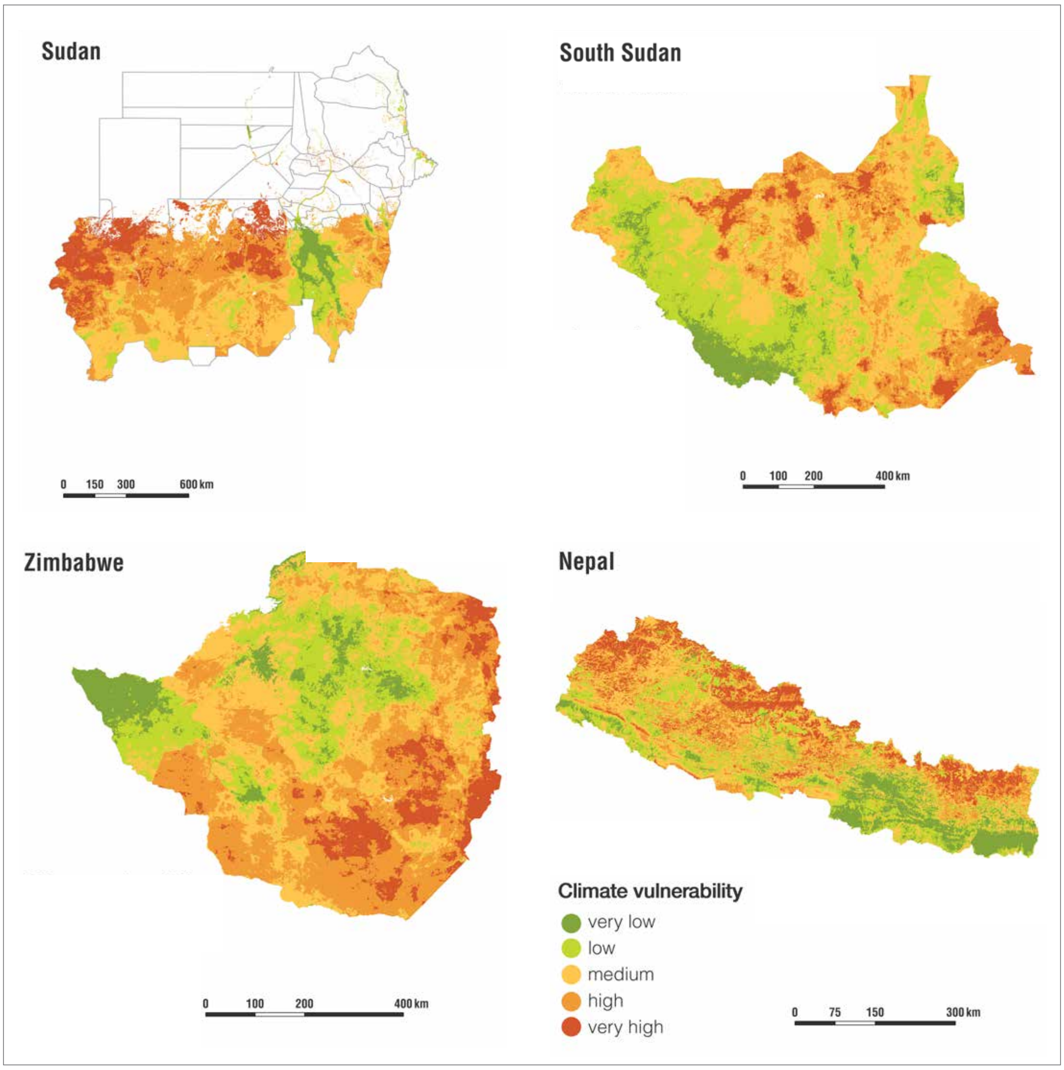

Figure 1. Levels of vulnerability in Sudan, South Sudan, Nepal and Zimbabwe.

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The IFAD GeoAdapt project has developed a tool that combines three measures into an index of vulnerability. These are the community's **sensitivity** to climate change, its **exposure** to the impact of climate change, and its **capacity** to adapt.

For example:

Farmers in a flood-prone area = **highly sensitive**;

The area is expected to flood more often due to heavy rains = **highly exposed**;

The area cannot adapt because it is very remote, so it is hard to find alternative sources of income = **lacking capacity**.

In such an example, the community would be classed as "very vulnerable" in the index.

A similar community that is less exposed (lives on slightly higher ground) or has alternatives (is closer to an urban area) can be expected to be less vulnerable.

> **Mapping the index gives governments and project designers an idea of where best to target projects to reduce the impact of climate change.**

Figure 1 shows example vulnerability maps for four countries: Dark red areas show concentrations of high climatic stress, high sensitivity and low adaptive capacity. The indicators chosen may vary from country to country and from project to project.

This tool was developed by GeoAdapt, or the "Mainstreaming of adaptation into IFAD's country strategies and investments through better use of geospatial data, analysis and tools" project. It builds on an approach developed by United States Agency for International Development (USAID) & NASA's Socio-Economic Data and Applications Center (SEDAC) (USAD/SEDAC, 2016).

Applications

The tool has been designed to support IFAD country strategies and project design in the following ways:

- Climate **risk screening** and identification of climate hazards to support the selection of adaptation measures;
- Geographical targeting of **vulnerable areas**;
- Estimating **potential target populations**, including gender, youth and nutrition; and
- Providing evidence-based information to **engage with governments** and other national stakeholders.

The tool is designed to be used by a country office or project design team with the support of IFAD's specialist geospatial unit.

Methodology

The tool calculates a vulnerability index based on **freely available geospatial datasets** that represent the three components of climate vulnerability, as defined by the Intergovernmental Panel on Climate Change (IPCC):

- **Exposure** to climate impacts (type and intensity of hazards);
- **Sensitivity** to climate impacts (predisposition of a system to suffer harm, loss, or damage as a consequence of a hazard event); and
- **Adaptive capacity** to climate impacts (capacity to deal with and respond to exposure and sensitivity).

Thresholds are assigned to each dataset and then converted into variables ranging from 0 to 1 (high/low) in order to make them comparable to each other. The index is calculated with the following formula:

VULNERABILITY INDEX = (Exposure + Sensitivity – Adaptive Capacity) / 3

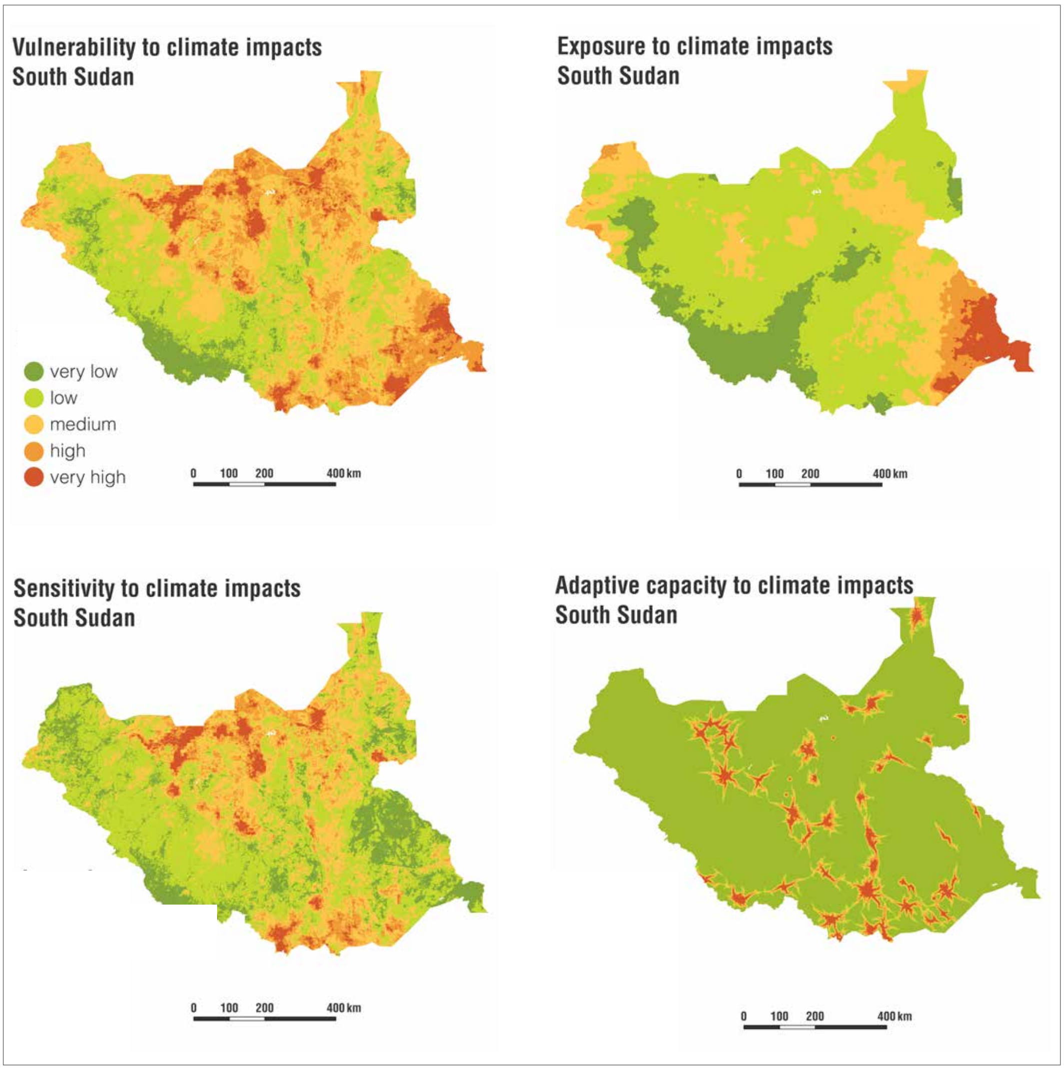

Figure 2. South Sudan: The index of vulnerability (top left) is the result of combining measures of community sensitivity (bottom left), exposure (top right) and adaptive capacity (bottom right).

Example of geospatial datasets used to estimate climate vulnerability

EXPOSURE	SENSITIVITY	ADAPTIVE CAPACITY
• Rainfall variability • Rainfall trend • Dry-spell • Heavy rains average and trend • Dry season frequency • Max temperature trend	• Flood exposure • Drought exposure • Erosion • Land degradation • Wildfires • Poverty (stunting, wasting, undernourished) • Conflicts	• Accessibility to urban centres • Irrigated areas • Labour force • Female education (20-24 years) • Youth

RESOURCES

Overview materials

[Presentation]

[Webinar]

Sudan | Country strategy design

[Maps]

[Area zonal statistics]

Zimbabwe | Small-holder Agriculture Cluster Project

[National maps]

[State maps]

[Dashboard]

[Area zonal statistics]

How it works

1. **Prepare data.** The team assembles the geospatial datasets that could be used in the model. They look for datasets that reflect the three elements – exposure, sensitivity and adaptive capacity – that will be needed to construct the index.

2. **Select the variables.** The team chooses those datasets that best represent the variables that affect vulnerability in the project area. It is not necessary to reflect every possible characteristic of the area (and indeed, the data required is unlikely to be available). Rather, the team selects proxy indicators that are credible, are readily available, and that best reflect the conditions on the ground.

3. **Run the model.** The analysts run the model with the data. This produces a draft version of a map that can be used as the basis of discussion.

4. **Get feedback.** The analysts present the preliminary outputs to the country office or design team for feedback. This is important to check that the map reflects the reality on the ground. It makes it possible to incorporate the local knowledge and insights of the country office or design team.

5. **Fine-tune the model.** The analysts adjust the model. For example, they may change the variables, or weight them to reflect their importance. This produces a set of maps that can then be processed and presented in the next stage.

6. **Visualize the results.** The analysts prepare a set of maps for the country office or design team to use. This may involve including information on demographics and administrative boundaries, and creating dashboards that permit the user to select specific indicators, zoom in on a particular area, or extract statistics for a particular municipality or region.

7. **Use the maps.** The country office or design team can then use the maps in many ways. They can be used to target project interventions to meet the most vulnerable people, identify potential interventions (infrastructure, education, marketing etc.), and negotiate with the government on activities and targeting.

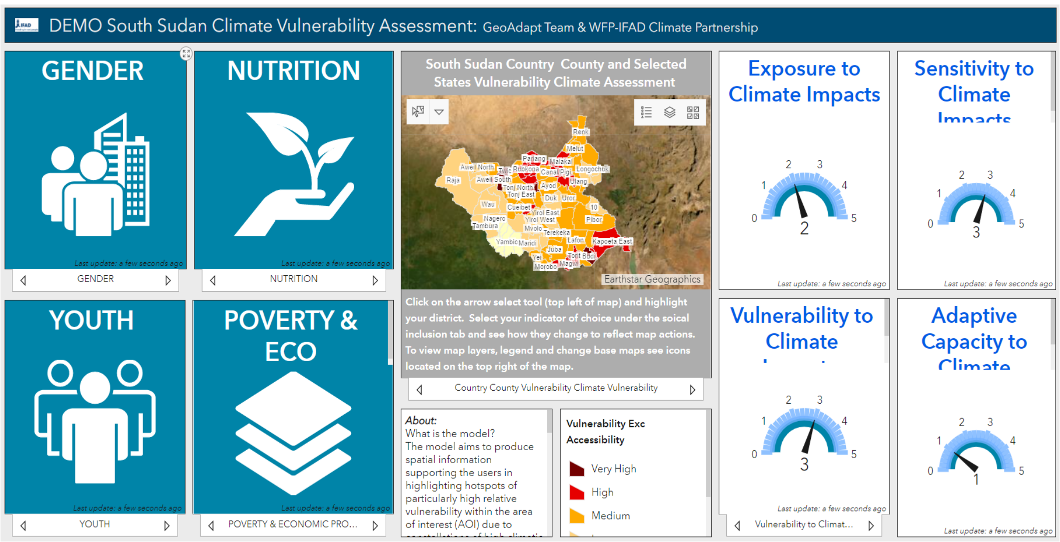

Figure 3. Results can be displayed in user-friendly dashboards.

RESOURCES

Nepal | Country strategy design

Maps

South Sudan | South Sudan Livelihoods Resilience Programme

National maps

State maps

Dashboard

Area zonal statistics

Informing investment strategies and projects

GeoScan: Data country profiles

A vast amount of geospatial data is available to inform IFAD investment decisions. Yet getting an overview of what geospatial data exists, assembling the data and analyzing it can be complex and time-consuming. GeoScan, an innovative IT application, aims to change this: it gives almost instant access to over 180 data layers from verified sources that can be used in the design of IFAD strategies and projects.

Web-app

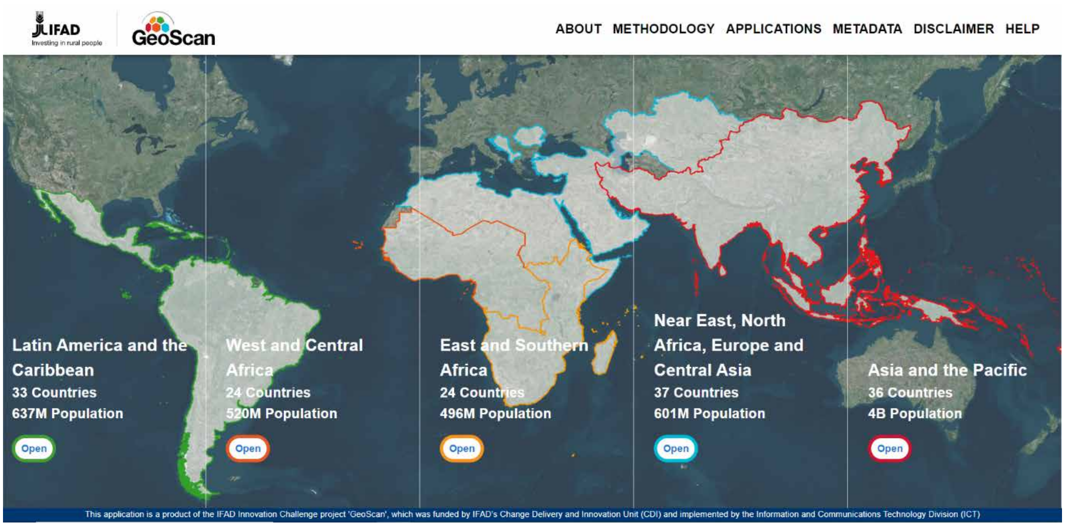

Figure 1. GeoScan gives access to geospatial data in all regions in which IFAD is active.

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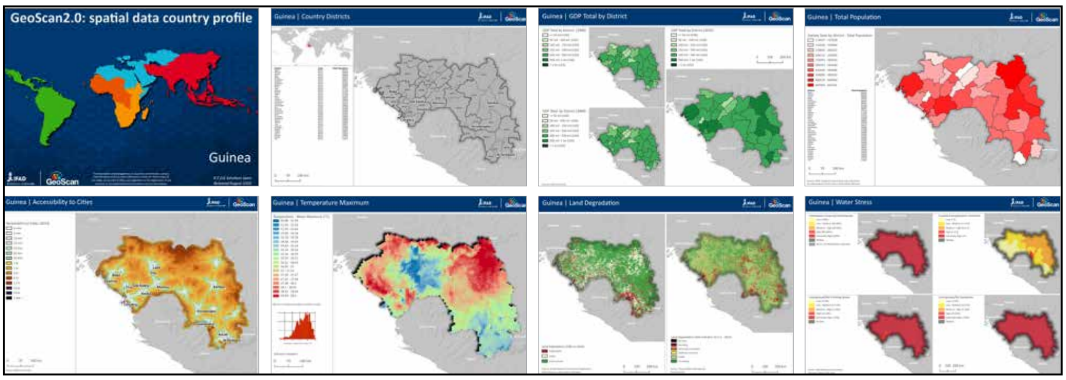

Figure 2. GeoScan offers a wealth of information about a country. For example, for Guinea, users can download over 90 pages of the country profile with maps and charts – a sample of which are shown here.

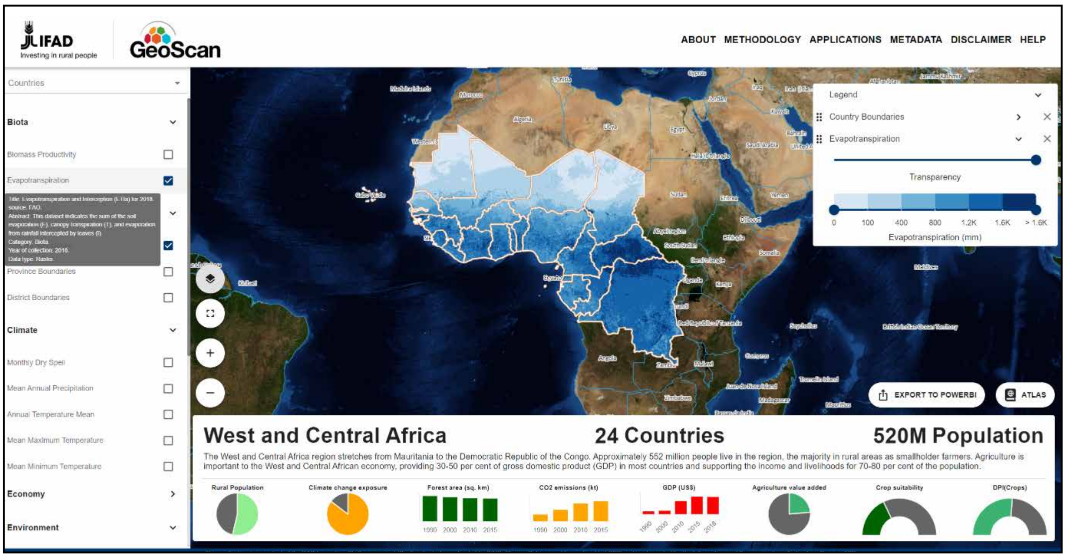

Figure 3. A view of GeoScan which displays a dataset on evapotranspiration (an indicator for water needs and vegetation productivity) for West and Central Africa from the Food and Agriculture Organization of the United Nations.

IFAD's web-application, GeoScan, offers a custom application for **designers of IFAD country strategies and projects**.

GeoScan's interactive and user-friendly dashboard provides ready-to-use geospatial data on a range of different themes. The themes are:

- **Boundaries**. Administrative boundaries at country, province and district level;
- **Biota**. Evapotranspiration and biomass productivity;
- **Climate**. Statistics on historic and projected climate variables, such as temperature and precipitation, as well as hazards such as drought, flood and landslide risk;
- **Economy**. Changes, over time, to the market value of goods and services produced, such as the national gross domestic product of a given nation;
- **Environment**. Layers such as land cover, ecosystems or protected areas;
- **Farming**. Data on crop suitability and livestock densities;
- **Geoscientific information**. Data on soil composition and structure, such as pH and depth to bedrock;
- **Health**. Statistics on human well-being, such as infant mortality and stunting;
- **Inland waters**. Information related to water and water risk;
- **Society**. Demographic data, such as child population or rural population projections; and
- **Transportation**. Roads and railways.

Reports, maps and statistics related to the themes can be generated for a country; these can then be downloaded in the form of an **atlas in PDF format**, giving users a quick overview. They can easily copy and paste maps into project design reports (see *figure 2*). No GIS skills are required.

Users who know GIS can **download the data in GIS format** for further analysis. The data can be opened with the QGIS software, an open-source desktop GIS application. The QGIS project file includes styles for each dataset for proper visualization.

RESOURCES

Web-application

Webinar

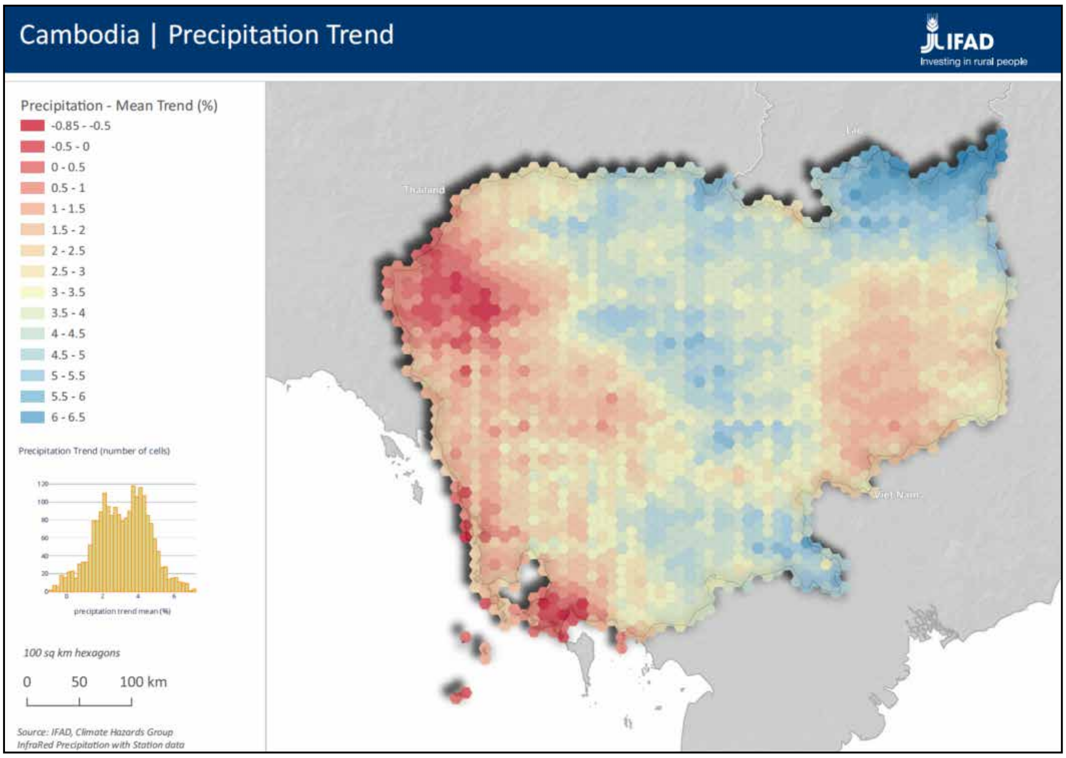

Figure 4. Precipitation trends for Cambodia based on rainfall estimates from 1981-2018 from CHIRPS (Climate Hazard Group InfraRed Precipitation with Station data).

GeoScan saves time. It would take weeks to manually assemble such data per country – whereas, with GeoScan, it can take a matter of minutes.

Data comes from a **range of sources** such as the Food and Agriculture Organization of the United Nations, United Nations Environmental Programme, NASA or the World Wildlife Fund. GeoScan provides details on where the layers come from, how they are displayed and if they have been processed.

GeoScan is currently only available for users who have access to IFAD's internal systems, although the Fund plans to make the web-application publicly available soon.

GeoScan was a **winning project** in the 2019 IFAD Innovation Challenge; and the application has been developed by IFAD's Information and Communications Technology Division.


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Vast catalogue on agricultural data

FAO Hand-in-Hand Geospatial Platform

Project designers need to factor in social, economic, climate, and many other variables in their project designs. The Hand-in-Hand Geospatial Platform is an excellent place to find the data they need. The user-friendly platform of the Food and Agriculture Organization of the United Nations (FAO) presents a vast catalogue on geospatial data on a wide range of themes relevant to agriculture.

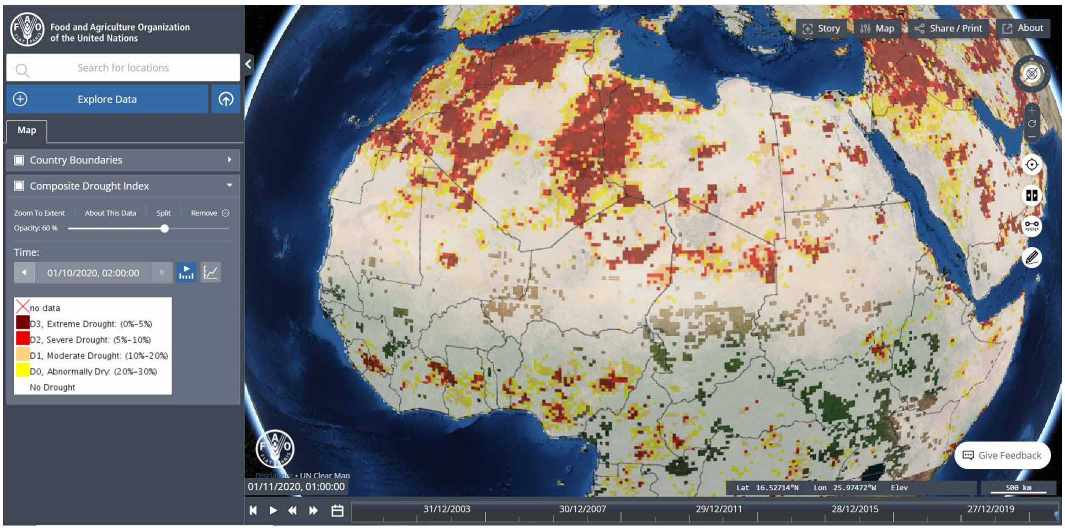

Figure 1. The user-friendly platform helps users to get a quick overview over a wide range of datasets. The screenshot shows a composite drought index. The index is calculated for every month and can be animated as a video.

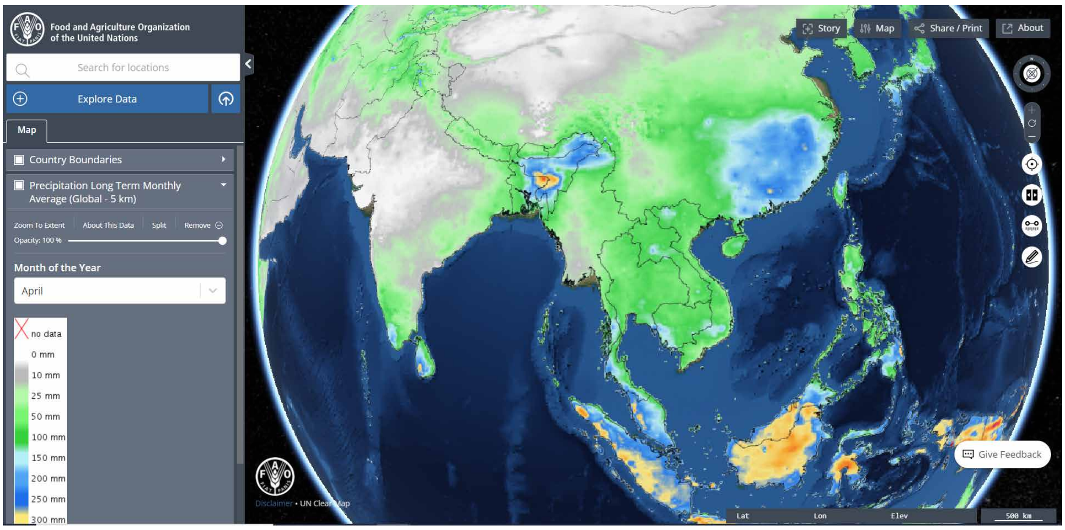

Figure 2. This screenshot shows historic average rainfall for April from the Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS), a 35+ year quasi-global rainfall data set.

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The Hand-in-Hand Geospatial Platform gives easy access to over **4,000 records combining over a million geospatial layers**. It gives access to FAO's own geospatial data, including indicators on food security and agricultural statistics from FAOSTAT. The platform also holds datasets from public data providers across the United Nations and NGOs, the private sector and space agencies. All data is freely available and well documented.

The data in the portal are organized into **twelve themes**: Food Security, Crops and Vegetation, Livestock, Trade and Production, Land, Water, Climate, Fishery, Forestry, Socioeconomic and Demographic, Novel Coronavirus (COVID-19), Boundaries and Backgrounds. *Table 1* shows the geospatial data that can be found in each of the themes.

Some of the datasets cover the whole globe. Others cover particular countries or regions.

The platform can be accessed online through a regular web-browser. You do not have to be a GIS expert to use the platform. It is easy to navigate, and no registration is required. Users can get a quick overview of a wide range of datasets.

The platform forms the basis of FAO's Hand-in-Hand Initiative, which aims to identify critical areas of policy intervention and public investment to unlock the potential for ending poverty and hunger (see *box 1*).

Finding geospatial data

Use the **"Explore Data" button** to search through the data catalogue. Simply type in a keyword in the search bar to find layers. You can also search for layers by theme: by clicking on the "Livestock" theme, for example, you get access to layers on livestock density and animal diseases.

Click on the **+ sign** next to the layer name to upload it to the data viewer. Layers are displayed on the left side.

All records in the catalogue contain "**metadata**" – descriptive information about the resource. Here users can read what the layer is showing, where it comes from and how it was calculated.

Comparing and visualizing data

Once a layer is loaded, you can view it on the map, and zoom in and out. You can add more layers – for example to compare current precipitation with historical averages. You can explore the layers in several ways:

- **Click on features**. Get information on a feature by clicking on its location (if you have the rainfall layer open, click on a location to show the rainfall at that place).
- **Choose a basemap**. Choose to view the map two-dimensional or as a globe. Select if you wish to view the layers against high-resolution imagery from Bing Maps or other background maps.
- **Compare layers side-by-side**. You can move a slider back and forth to compare two different sets of layers on the same map.
- **Upload data**. You can upload your own data and view it against the layers you have selected.
- **View graphics and watch map animations**. For data in a time series (such as a monthly drought index), you can play a video to see how it changes over time. It is possible to generate graphics of the time series.

RESOURCES

Geospatial platform

Hand-in-Hand initiative

Box 1. FAO's Hand-in-Hand Initiative

The Geospatial Platform forms the basis of FAO's Hand-in-Hand Initiative, which aims to accelerate agricultural transformation and sustainable rural development to eradicate poverty and end hunger and malnutrition. It aims to complement existing information and coordination mechanisms. It provides matchmaking services to link donors and national governments to take advantage of economic opportunities and to improve targeting and tailoring of policy interventions, innovation, finance and investment, and institutional reform.

More information

Data analysis

The platform is designed to provide access to datasets and to allow users to visualize them on screen. To do more detailed analysis of the data, users will have to use other applications. The Hand-in-Hand platform gives access to System for Earth Observation Data Access, Processing and Analysis for Land Monitoring (SEPAL) and EarthMap – two applications that are featured elsewhere in this catalogue. Users can also download data for further analysis.

The platform also offers web-mapping services for developers who wish to display the layers in other applications.

The FAO Hand-in-Hand Geospatial Platform is already a valuable and easy-to-use tool. It is under constant development, so further improvements are expected and more datasets will be added.

Table 1. Examples of what to find on the FAO Hand-in-Hand Geospatial Platform

Theme	Geospatial data
Food security	Suite of food security indicators such as from FAOSTAT, the World Bank, and the Integrated Food Security Phase Classification (IPC), as well as location data of armed conflicts.
Crops and vegetation	Datasets on vegetation health and crop production, yields, calendars and diseases, as well as data from FAO's Global Agricultural Drought Monitoring System, and CropWatch – a global crop monitoring system.
Livestock	Data on livestock production, animal density and location of animal disease events.
Trade and production	Data on agricultural trade, agricultural commodity prices, and production values and indices.
Land	Datasets on soils, elevation models, land cover and use.
Water	Data on hydrological basins, rivers, locations of dams and irrigation areas, statistics on water usage, and remote sensing data on water productivity, amongst others.
Climate	Data on climatic variables such as rainfall, temperature, wind, as well as on drought and greenhouse gas emissions.
Fishery	Data on fish catch areas.
Forestry	Data on forest area, ownership and management; remote sensing products on forests such as Normalized Difference Vegetation Index
Socioeconomic and demographic	Maps on human population, travel time and costs, infrastructure such as roads, railways and airports, access to electricity, night lights and telecommunications.
Novel Coronavirus (COVID-19)	Data on cases, deaths and impact on food systems due to COVID-19, as well as crop calendar recommendations.
Boundaries and backgrounds	Country boundaries, administrative layers, major cities and protected areas.

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Web-app

User-friendly tool for complex land monitoring

Earth Map

Earth Map is an innovative, free and open-source tool developed by the Food and Agriculture Organization of the United Nations (FAO). Based on Google Earth Engine, the tool makes it possible to visualize, process and analyse satellite imagery and global datasets on a wide range of topics.

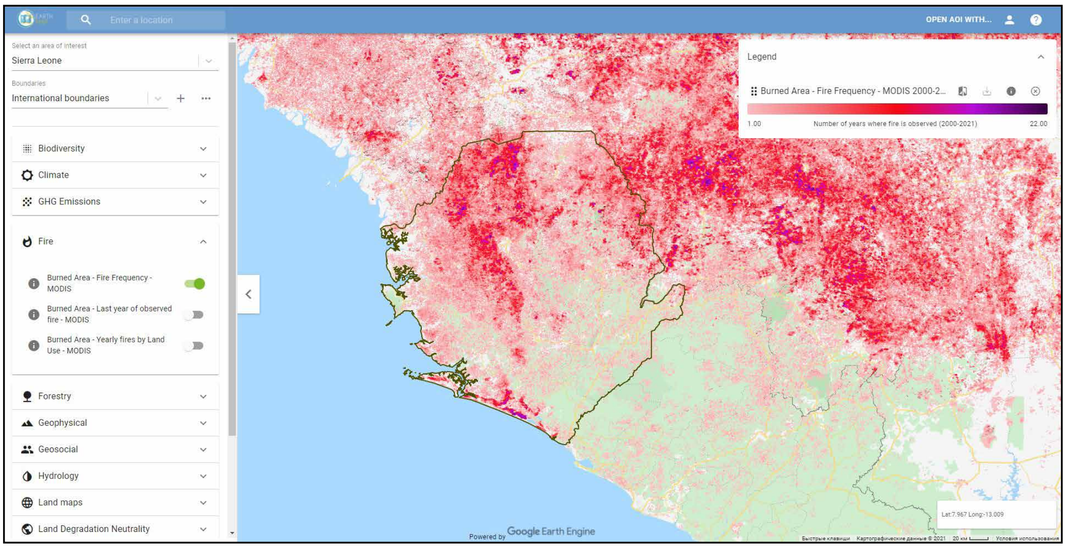

Figure 1. Farmers in Sierra Leone normally use fire to clear a patch of land in the forest so they can grow rice and other crops. This layer from NASA's [MODIS dataset] shows the number of years in which a fire was detected in the period from 2000 to 2018. The darker areas are locations that were burned frequently.

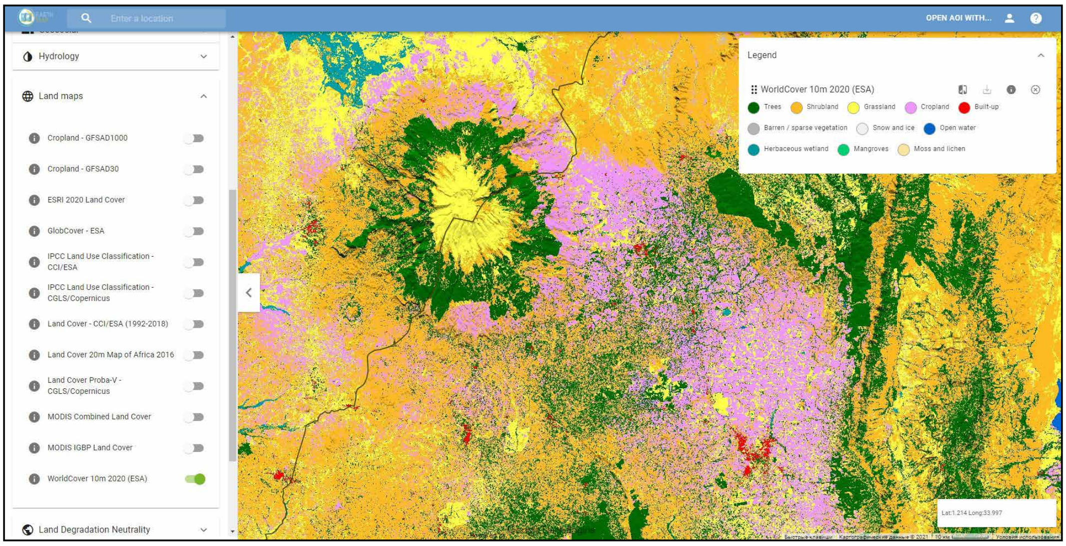

Figure 2. Earth Map gives access to a wide range of datasets. This screenshot shows a land cover map for 2020 at 10 metre resolution from the European Space Agency. It shows the diverse landscape of cropland, forest areas and shrubland around the Mount Elgon volcano on the border between Kenya and Uganda.

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Earth Map allows users to zoom in on any area of the world and see data in that location on a wide range of themes, including climate, social elements such as population density and level of urbanization, vegetation, land degradation neutrality, water, satellite images, land maps, forestry, fires, geophysical features, soils and biodiversity.

Users choose their geographical area of interest – a region, country or specific area – and then select which dataset they wish to visualize for that location. The data and statistics are then layered on top of the map. Statistics can be aggregated at different timeframes (yearly, monthly averages and monthly time series) and time periods.

Layers include, for example: land cover, using the European Space Agency's Climate Change Initiative dataset; temperature and precipitation ERA5 data from the European Centre for Medium-Range Weather Forecasts; and tree cover loss from the Global Forest Change project of the University of Maryland.

Earth Map builds on the **computing power and datasets of Google Earth Engine**, a cloud-based processing platform. This works through a standard web browser such as Google Chrome. Users can quickly **generate statistics on any device** without having to install any software or download any data. They do not need any prior knowledge of remote sensing or GIS to use the tool.

Applications

Earth Map is applied in a number of IFAD-funded operations. The tool can support the design, planning and monitoring of climate change adaptation and mitigation projects:

- **Design.** It can provide project staff with information on climate, vegetation, burned areas, land cover and others, allowing them to understand these issues and how they affect people in the project area;
- **Planning.** It can provide data to plan investments such as introducing new crops, calculating irrigation capabilities and designing restoration activities; and
- **Monitoring and evaluation.** It makes it possible to assess the effects of project activities on crops, forests or infrastructure development.

RESOURCES

[Earth Map web-tool]
[Earth Map Help Center]
[Earth Map description on openforis]

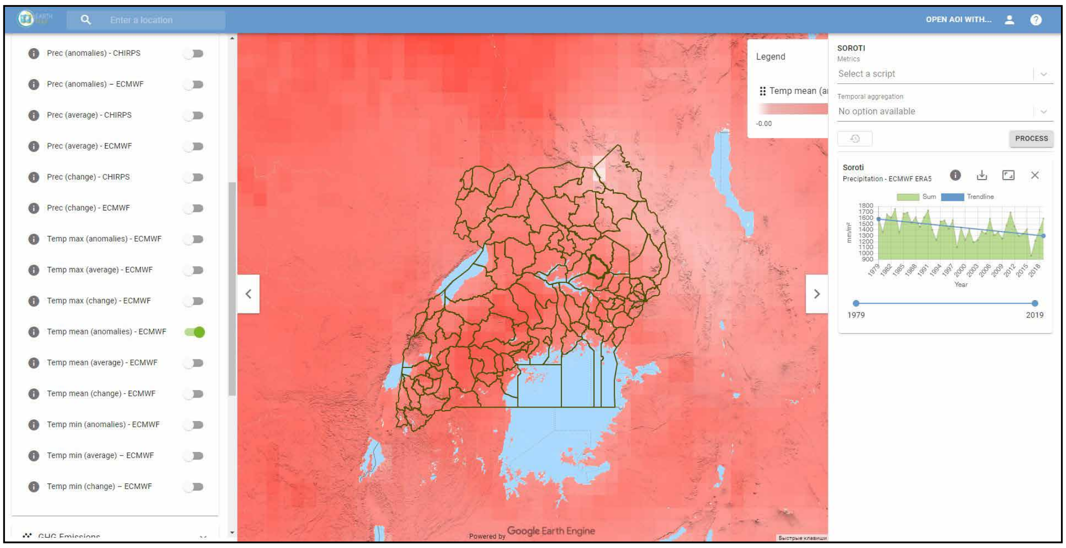

Figure 3. This screenshot shows: the temperature anomalies for Uganda (darker red = temperature deviates more strongly from the standard), and declining rainfall in Soroti district (in the centre east of the country, with bold outline), as shown in the graph on the right. Source: ERA5 data.

Cloud-computing for analysing satellite imagery

SEPAL: Land monitoring platform

Satellites from the European Union's Earth Observation programme alone collect 12,000 gigabytes of satellite imagery every day. Such images can help rural development projects monitor their impact on forests, pastures and cropland. But viewing and manipulating the data requires enormous computing power, storage and coding skills. The System for Earth Observation Data Access, Processing and Analysis for Land Monitoring – or SEPAL – a cloud computing-based platform, allows users to access and process satellite imagery without having to download any data. Users can quickly and easily create composite images, classify land and map changes without having to write any code.

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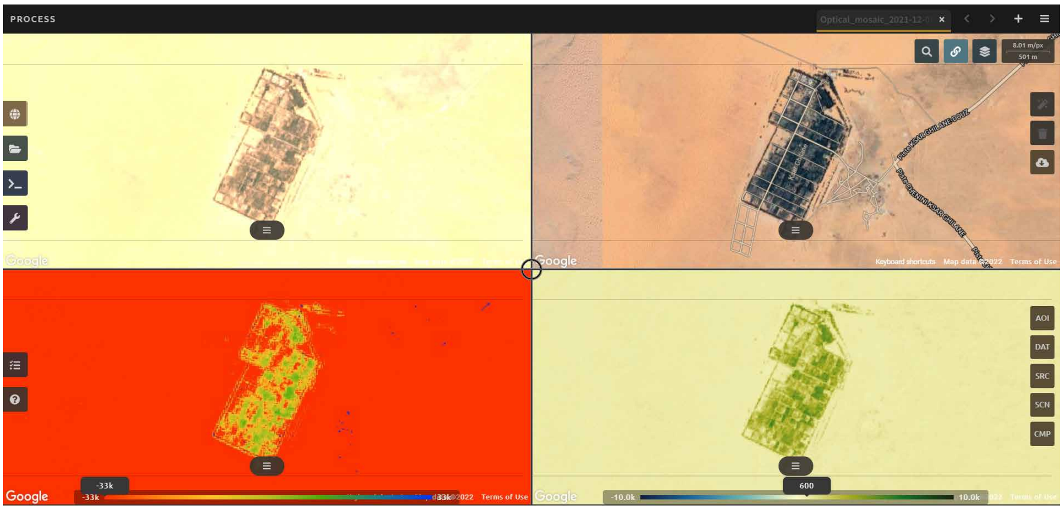

Figure 1. IFAD-funded irrigation development in a rural settlement in Tunisia: Top left: Composite image of Sentinel 2 images at 10m resolution; Top right: Google satellite imagery at very high resolution; Bottom right: index to highlight built-up areas, and; Bottom left: index for vegetation health.

SEPAL is a free and open-source platform run by the Food and Agriculture Organization of the United Nations (FAO). It provides **"big-data" processing services** for land monitoring with remote sensing data.

SEPAL offers access to satellite images through a user-friendly interface. The data and processing are managed on cloud-based supercomputers, that allow users to **process large amounts of data without needing a lot of bandwidth** or investing in expensive hardware. The platform is free and open-source.

More than 8,000 users from over 130 countries are registered to use SEPAL. SEPAL gives its users access to imagery from the satellite families of **Sentinel** (operated by the European Space Agency), **Landsat** (operated by NASA), **Advanced Land Observing Satellite** (ALOS) (operated by the Japanese Space Agency, JAXA), **Planet** (an American satellite company), in addition to allowing the integration of any other imagery sources.

The highest resolution available is from Planet imagery, through the NICFI data program, which is at 5 meters, available for tropical countries and updated daily.

Author: Oliver Mundy | Design: Tuuli Sauren | Maps: Rakhat Zhanuzakova | Editing: John Laird

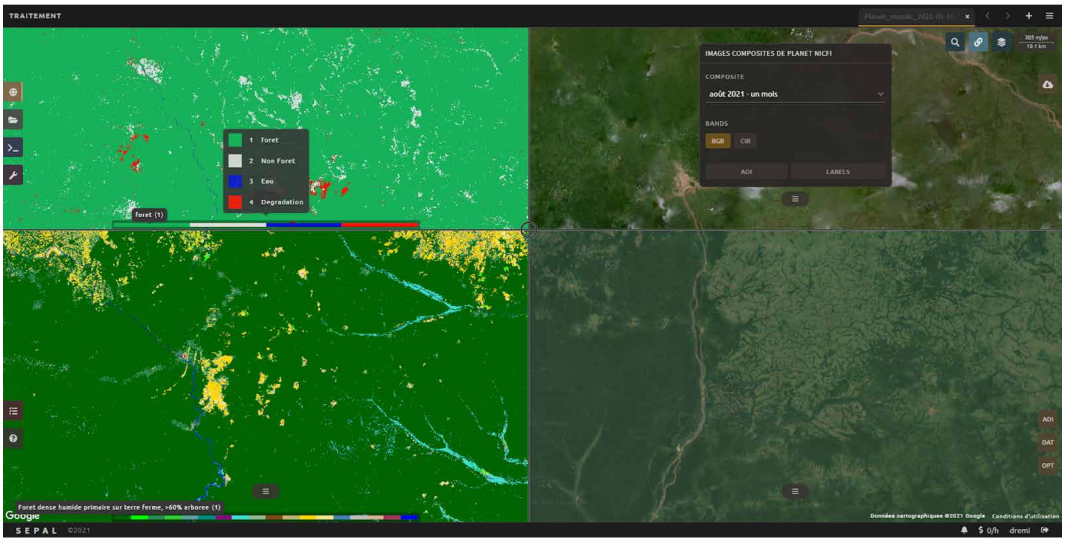

Figure 2. This screenshot from SEPAL shows an [FAO assessment] undertaken in Congo. Top left: Degraded and deforested areas are in red; Bottom left: A forest type map; Top right: Planet satellite imagery at 5m resolution; Bottom right: Google satellite imagery at very high resolution.

Analysis "recipes"

SEPAL makes things easy for users by offering "recipes" for the most common types of analysis. Each recipe contains a particular mix of ingredients – satellite bandwidths, time frames, etc. – to highlight particular types of information.

Combine satellite images and compute indices

Satellites measure the earth's reflection and capture the data in different bandwidths. To generate a composite image, you first choose the country or district you are interested in. You then select the satellite imagery (Sentinel, Landsat, etc.) and time period you wish to analyse.

You can then generate up to **eight combinations on how to display the bandwidths**, and you can compute as many as **15 indices**. A standard image uses the red, green and blue bands. You can also choose other wavelengths (such as near-infrared) or among over a dozen different preset alternatives.

Computing the bands into indices can help to highlight certain aspects. To highlight **burned areas**, for example, you can choose the Normalized Burn Ratio (NBR). To monitor **vegetation health**, you can use the Normalized Difference Vegetation Index (NDVI) or Enhanced Vegetation Index (EVI). The index-based built-up index (IBI) helps identify **built up areas**. *Table 1* provides guidance on what to use an index for.

Classify land cover and analyse land use change

SEPAL provides an easy, step-through recipe to classify areas into different classes to map cropland, forest, grassland, etc. These maps can be used to monitor land-use changes such as the planting of forests, deforestation, or the expansion of urban areas.

Calculate time series

Simply drop a pin on your map, and you can generate a timeline for a bandwidth or an indicator. You can choose from among 25 different indicators. This helps to understand the dynamics at a given location over a period of time.

Access to processing chains and applications

Users have the ability to choose their computing power and run a variety of applications ranging from near real time fire monitoring using daily high resolution imagery to soil moisture mapping for monitoring peatland restoration (among other applications). For advanced users that would like to run custom analyses, Jupyter Notebook and RStudio are available in SEPAL, providing a spectrum of applications for someone with coding experience. Advanced applications include:

- Real time monitoring of active fires;
- Soil moisture mapping for monitoring peatland restoration;
- Different time series analysis;

RESOURCES

[SEPAL platform]
[Documentation]
[Story map]

Table 1. Examples of combinations and indices to visualize and analyse satellite imagery in SEPAL

To do this	Use this combination, index or tools (examples)
Display imagery	• Combination of red, green and blue bands • False colour composite to differentiate between vegetation types (nir, swir1, red)
Monitor health of crops and vegetation	• Normalized Difference Vegetation Index (NDVI) • Enhanced Vegetation Index (EVI)
Identify built-up areas	• Index-based built-up index (IBI)
Identify burned areas	• Normalized Burn Ratio (NBR)
Check for flooding	• Sentinel 1 time series (VV/VH)
Identify deforested areas	• Normalized Difference Fraction Index (NDFI) • Normalized Difference Vegetation Index (NDVI) • Normalized Difference Moisture Index (NDMI)

- Proxy maps for post-disaster assessment (e.g. hurricanes, flooding damage); and
- Deforestation analysis.

Applications

SEPAL is of particular interest for rural development projects that aim to improve the management of natural resources such as soils, water, forests, and rangelands. It is also a valuable tool for monitoring irrigation projects.

SEPAL can be used to visualize data, and you can extract computed data from SEPAL to feed into another programme for further analysis. Some examples of possible uses:

Project design

- Identify problems to be addressed (e.g. low vegetation cover);
- Identify areas where interventions are needed;
- Establish baseline data, set targets and estimate costs and benefits; and
- Identify control areas without intervention.

Implementation

- Monitor progress from year to year (e.g. in an irrigation scheme);
- Monitor progress in different project locations;
- Check the situation on a daily basis (e.g. during disasters); and
- Generate images to use with project staff and clients.

Evaluation

- Compare the same area over time;
- Compare the intervention area with the control area;
- Identify areas of potential positive and negative spread effects;
- Calculate indices to use as indicators (e.g. vegetation cover); and
- Specific indicator monitoring tools (e.g. Sustainable Development Goals 15.4.2 and 15.3.1).

Pros and cons

Advantages

- Free and open source tools linking to the best available science and methods for remote sensing.
- SEPAL is a quick and easy way to create and visualize composite images of satellite images.
- It does not require any specific hardware or software, only an internet connection.
- SEPAL offers ready-made recipes to create custom satellite imagery data that is ready for analysis.
- The platform is under constant development: it will get even easier to use.
- Extensive documentation and tutorials are available for the platform.

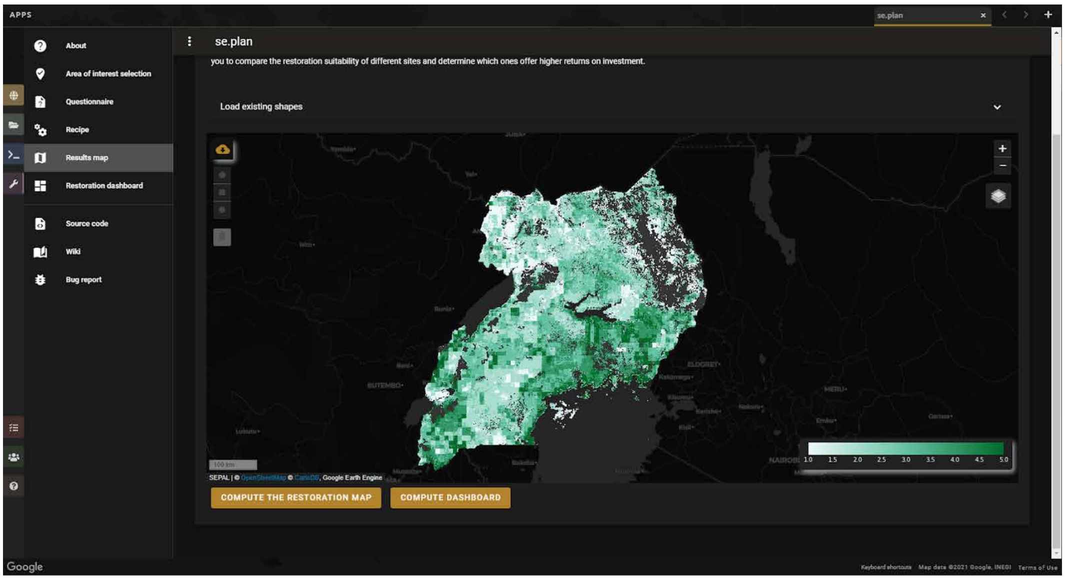

Figure 3. This forest restoration potential map for Uganda shows where forest restoration is most cost effective. Darker green shows areas where more benefits are captured with lower costs. The map was generated by se.plan, a tool in SEPAL for forest restoration planning and decision support.

Limitations

- SEPAL still requires a certain level of knowledge of remote sensing and knowledge on how to interpret data.
- It is necessary to set up linkages to Google Earth Engine and Planet to access the full functionality of the platform.
- The resolution of imagery may be too coarse to see details of e.g. infrastructure projects.
- It is necessary to have geospatial boundaries of project locations in order to track changes.

The future of crop production

Innovative geospatial portal on agro-ecological zoning

Climate change will affect how, when and where farmers produce their crops in the future. For example, crops that today grow well in an area might not do so in coming years. That means that farmers will have to adapt their practices and perhaps grow crops differently. Governments and development agencies need to anticipate the impacts of climate change so they can design programmes to support these transitions. The fourth version of the Food and Agriculture Organization of the United Nations (FAO) new Global Agro-Ecological Zoning portal (GAEZv4) provides policymakers and analysts with a wealth of data on agricultural production and the factors that influence it.

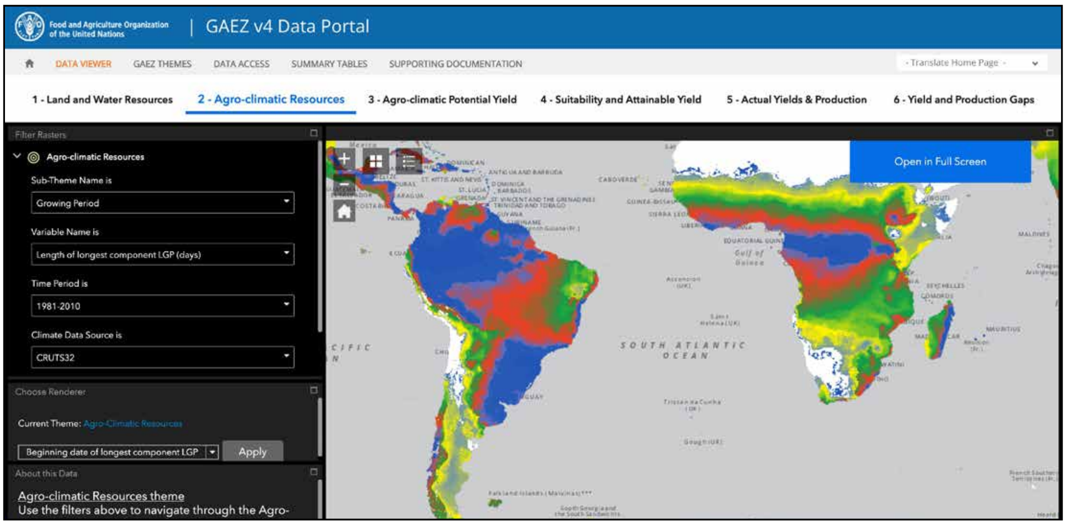

Figure 1. The portal gives access to a number of useful layers such as the once shown above. In this case the number of days where agricultural production is possible for the period 1981 to 2010. Similar information is also available for future years.

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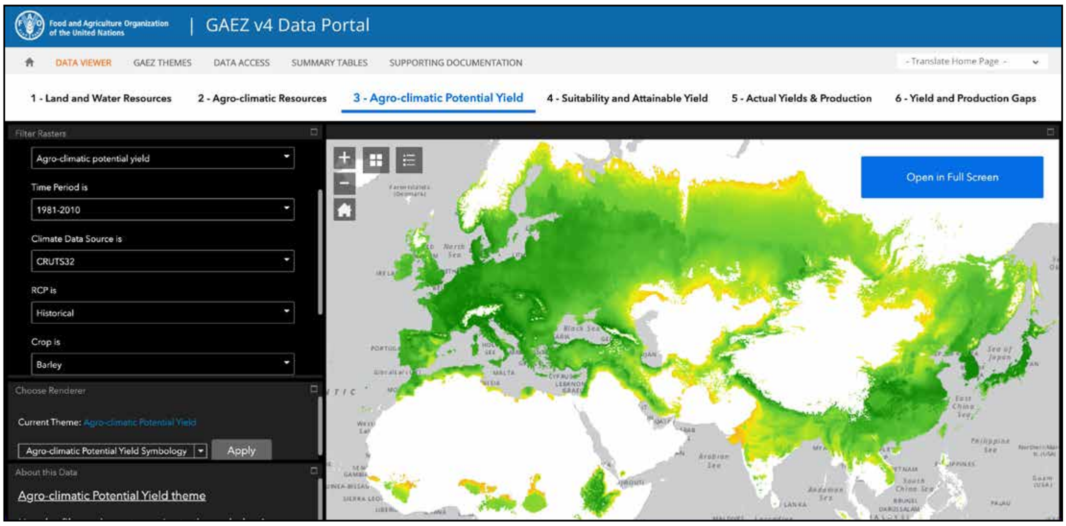

Figure 2. Comparing historical and future scenarios helps understand how crop suitability and productivity will change in the future. This picture shows the productivity of barley from 1981 to 2010. When compared to future scenarios the potential areas for barley and many other cereals will most likely shift to the north.

GAEZv4 provides a **huge range of geospatial data** to support project managers and decision makers. The platform covers **up to 53 major crops**, from alfalfa to yams. It presents **crop-specific potential productivity, land suitability, actual production and yield gaps** in the form of customizable maps. Users can relate this information to land and water resources (such as soil type and slope), and to climatic information such as rainfall, temperature, and growing period. Various time frames can be chosen: from **1961-present or until 2099**, based on forward looking climate models.

That allows them to generate a wide range of information for many uses. Some examples:

- **Climate change.** A programme preparing for climate-change adaptation can use the platform to forecast the expected climate changes and their likely effects on crop production in each location across a country.
- **Land suitability.** Ministries of agriculture can see which areas of the country are suitable for growing certain crops.
- **Economic and financial analysis.** Economists can use the yield and production data to predict the costs, incomes and profits for crops in particular areas, or to compare the profitability of different land use options.
- **Land use planning.** Agencies focusing on particular land types (such as rangeland or irrigated areas) can extract the data for land use planning and infrastructure developments.

Data portal

The data portal allows users to **search, view and download a specific layer**. The data cover the whole world at a common spatial resolution of around 9 x 9 km per pixel, with some types of data (such as soil suitability, slope and land cover) at a higher resolution of under 1 km per pixel. It is possible to extract and download the information in GIS formats so they can be combined with other geospatial information to allow further analysis.

See the webinar link to the right for guidance on how to use the data portal.

RESOURCES

Data portal
Story map
Webinar
Video

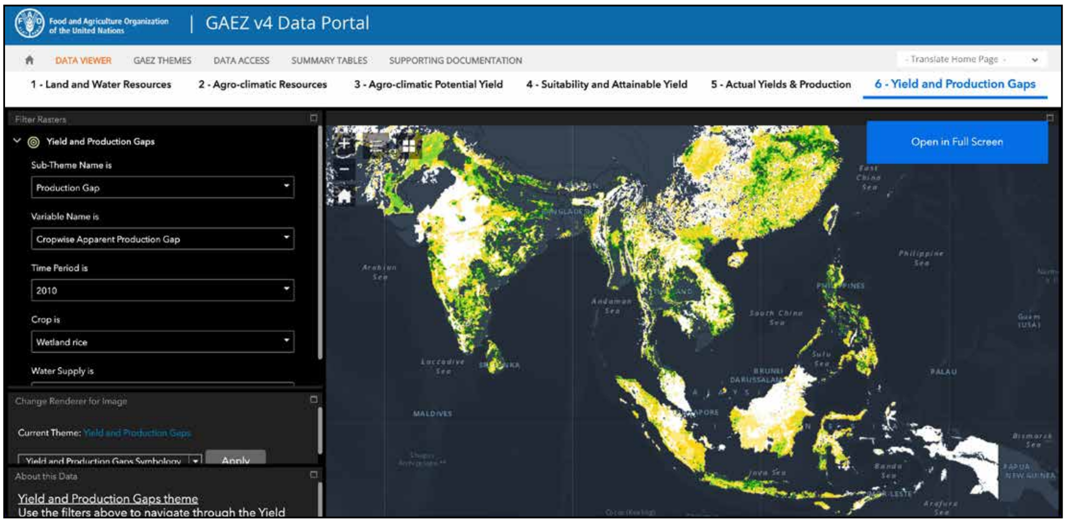

Figure 3. This picture shows the yield gap of rice, a crop that is widely grown in Asia. The yield gap is the difference between the potential maximum production and actual production. Such maps help target services for rice producers to increase their yields.

Six themes

The data in the portal are organized in six themes that reflect different stages of data analysis and user needs. The first two concern the resources that influence crops and their productivity:

1. **Land and water resources.** This is used mainly as input to the models to characterize land use, soil resources, topography, water resources, and selected socio-economic data.

2. **Agroclimatic resources.** This provides an overall characterization of climate regimes and agro-climatic conditions affecting the overall agricultural productivity and suitability. This information includes historical time-series and 30-year averages covering 1961-2010, plus predictions for the future – the periods 2011-2040, 2041-2070, and 2070-2099 for multiple climate models and scenarios.

The remaining four themes concern the crops themselves:

3. **Agroclimatic potential yield.** This provides information for each crop on its agroclimatic yield, constraint factors, growth cycle attributes, and land utilization types.

4. **Suitability and attainable yield.** This has information for 53 crops on land suitability, agroecological attainable yield, and crop-water deficit.

5. **Actual yields and production.** This includes the actual harvested area, yield and production for 26 major crops or crop groups, separately in rainfed and irrigated cropland, plus the estimated value of production at 2000 prices.

6. **Yield and production gaps.** This calculates the difference between the actual and potential yields of 22 major crops for rainfed and irrigated cropland.

Development

GAEZv4 is jointly developed by FAO and the International Institute for Applied Systems Analysis (IIASA), in collaboration with a number of partners including the Asian Institute of Technology (AIT) and the Environmental Systems Research Institute (ESRI). The fifth version of the Global Agro-Ecological Zoning (GAEZv5) is under development.

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Learning programme

Securing land rights with participatory GIS mapping

Secure tenure is not only important for sustainable land and natural resource use; it is also important for social inclusion and climate change adaptation. Farmers who do not have secure tenure of the land where they grow crops or keep livestock may be **unwilling to invest in it**. So improving their tenure security is essential. Geospatial tools, such as participatory GIS land recordation and mapping, provide new ways of recording land **parcels and tenure arrangements cheaply, quickly and effectively**. This information can then be fed into land registers.

To aid development partners, IFAD and the Food and Agriculture Organization of the United Nations (FAO) have developed "GeoTech4Tenure": a free, online course that provides participants with techniques and tools on how to **select the most appropriate technologies to record land** in rural development projects.

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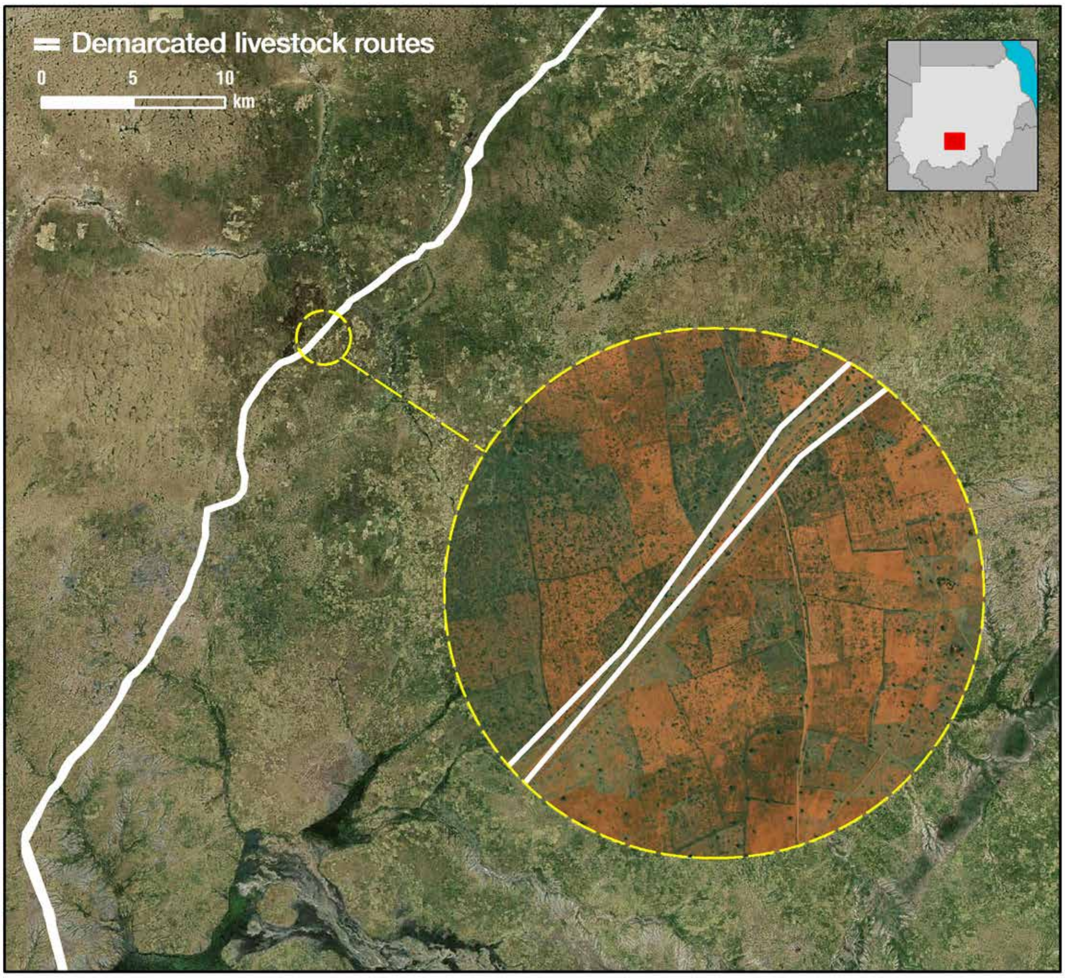

Figure 1. IFAD's Livestock Marketing and Resilience Programme in Sudan helps communities co-manage livestock routes and avoid encroachment on the livestock route which is shown by the double white lines in the image above.

Author: Oliver Mundy | Design: Tuuli Sauren | Maps: Rakhat Zhanuzakova | Editing: John Laird

Figure 2. IFAD's Smallholder Tea and Rubber Revitalization Project in Sri Lanka is helping farmers to grow tea and rubber. At the same time, GIS technology is being used to map farmers' plots – see the image above – in order to issue land titles.

Secure land tenure is a foundation for climate change adaptation. Secure rights are especially important for women, youth and indigenous communities. Tenure insecurity causes conflicts, marginalization of more vulnerable groups, lower productivity and land degradation.

Farmers who are willing to invest time and resources in adapting their practices to a changing climate need confidence that they will still be able to use their land and reap **its benefits in future**. If their tenure rights are not secure, they cannot be confident that they and their children will benefit, and they will not be willing to make investments and adapt their farming practices.

A number of IFAD-funded projects help farmers record their land to **improve their tenure security**. Participatory methods and geospatial technology can help to achieve this.

The GeoTech4Tenure online course serves development partners and organizations interested or involved in projects involving IFAD or FAO. It equips them with the skills needed to find solutions to secure tenure rights by combining participatory methods and geospatial technology.

Conventional land-related services are often expensive, outdated, not accessible, or not adapted to the community's prevailing tenure system. Too often, they are slow, expensive, overly precise and bureaucratic. As a result, people do not use them: land parcels are subdivided, are built on or change hands without these transactions being reflected in the official records.

Conventional land administration may also fail to recognize the different customary rights that people may have to a particular piece of land. A farmer may use the land in the wet season to grow crops, but a herder uses the land for grazing after the harvest. Others may have the right to harvest fruit, gather firewood or collect water on the same piece of land.

The GeoTech4Tenure course promotes a more flexible approach known as **fit-for-purpose land administration**. This is tailored to the local situation and a flexible approach to capture a range of rights in different contexts.

While geospatial technologies are not a silver bullet that can solve such problems, they can provide part of the solution. They are particularly useful in participatory mapping, allowing local people to record their claims to land. Handheld GIS equipment can be used to record the locations of land parcels, map boundaries, and record overlapping claims. Satellite and aerial images can help locate parcels and landscape features such as forests, roads and rivers.

RESOURCES

Course information
Webinar series
Emailing list

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Figure 3. In Cambodia, FAO used a set of free, open-source tools to help communities strengthen the governance of community forests. This helped to protect forests from being exploited.

Course contents

The participants learn:

- The core concepts of tenure, tenure security and tenure governance;
- The challenges and opportunities surrounding tenure issues for land-based investments;
- Methods for participatory land recordation and mapping;
- The use of different geospatial technologies for land recordation; and
- The criteria for selecting the most appropriate technologies for a given situation.

The course contains the following components:

- An e-learning and technical guide;
- Peer-to-peer learning opportunities with people from all over the world;
- Online workshops;
- Virtual visits to learning sites;
- Online mentoring from experienced land tenure experts; and
- Project work on integrating land recordation within an IFAD-supported project.

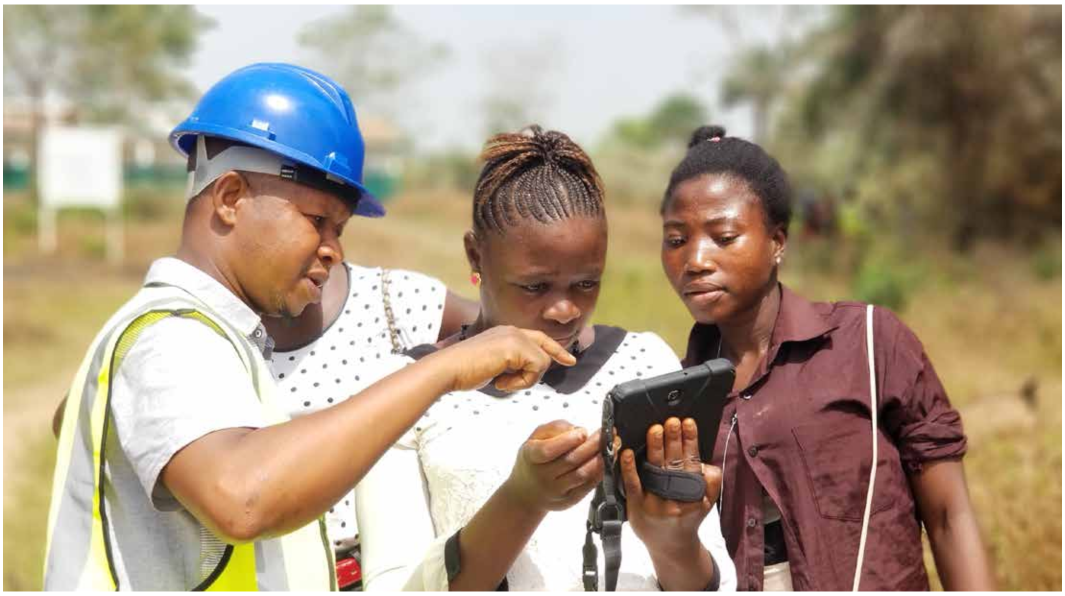
The course runs regularly, takes six weeks and requires a commitment of 4-5 hours per week. The first editions of the course are in English. Courses in Spanish and French are being planned.

This course has been developed in collaboration with FAO. It is funded by IFAD's Innovation Challenge programme, with additional financial and technical support from FAO and IFAD.

Participants can subscribe to the land tenure email list to stay up-to-date with the latest developments of the programme.

Webinar series

The learning programme is accompanied by a series of webinars where technology providers present their software solutions for land recordation in a participatory context and give examples how they are applied in practice. Each webinar lasts 30 minutes.



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Mapping climate investments

Integrating GIS in monitoring and evaluation

Monitoring and evaluation (M&E) generally involves gathering information on the situation at the start of a project (the "baseline"), at various intervals during the implementation, and after the project has finished. Many of the measures implemented in a project have a spatial dimension – they can be mapped. Doing so gives project managers and donors valuable insights about the project's activities and impacts. IFAD's GeoM&E initiative has drafted guidelines on how to integrate geographical information systems (GIS) into the M&E work of the projects it funds.

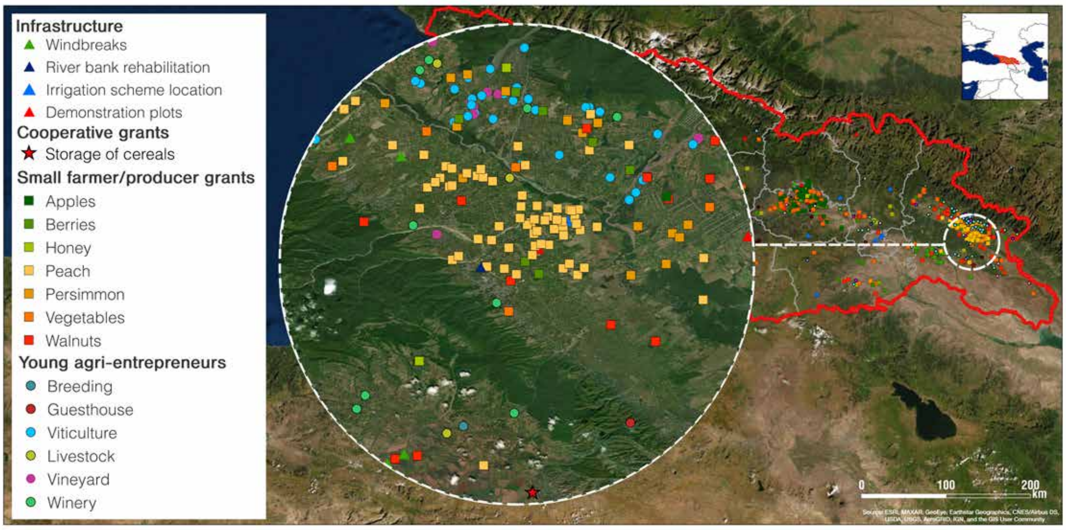

Figure 1. The Agriculture Modernization, Market Access and Resilience Project in Georgia, which ended in 2021, mapped the enterprises, producer groups and infrastructure that it supported.

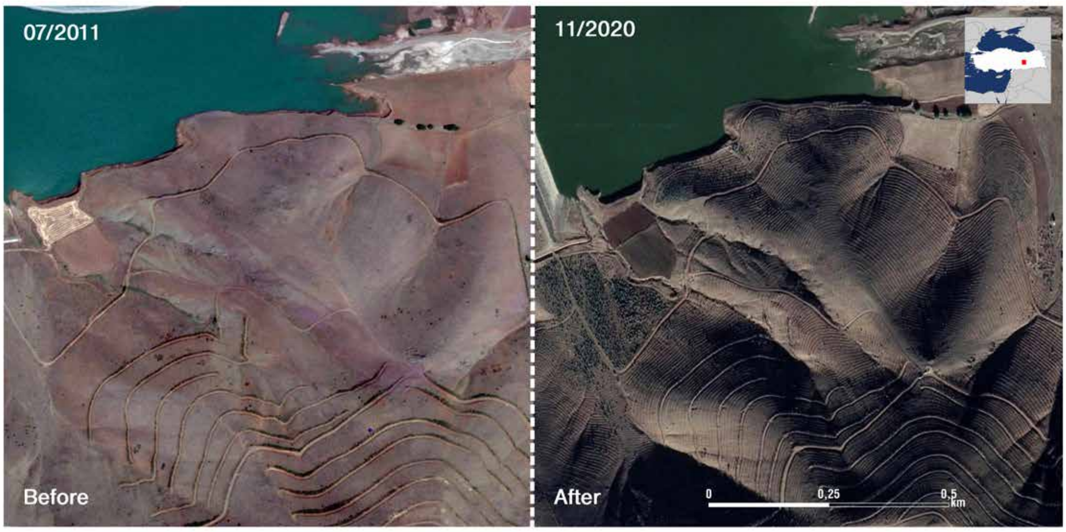

Figure 2. The images above show terracing and afforestation of the Murat River Watershed Rehabilitation Project in Turkey to help conserve soil and water. Satellite imagery reveals the contours of the terraces after they have been constructed.

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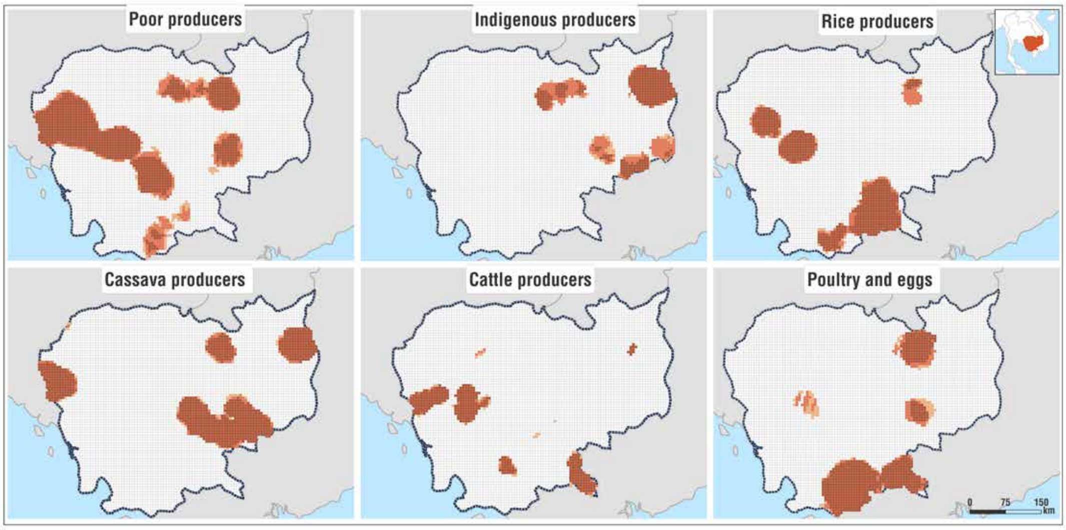

Figure 3. The Agricultural Services Programme for Innovation, Resilience and Extension and Accelerating Inclusive Markets for Smallholders project in Cambodia rigorously collected data of over 140,000 producer households. These rich datasets made it possible to do hotspot analysis: to create maps suggesting where support to indigenous and poor producers should concentrate, prioritize where best to provide extension services for different commodities, and find ideal locations of agricultural extension centres.

Roads, irrigation facilities, wells, crop-processing facilities, marketplaces, afforestation, erosion-control measures, pasture rehabilitation, rural finance … these are typical interventions for rural development projects. They are intimately related to climate change. Knowing where they are makes it easier to monitor and evaluate them.

Collecting geospatial data as part of the regular planning and M&E process makes it possible to ensure that project interventions are climate-resilient and sustainable. It also opens up new possibilities for improving the effectiveness of activities. Some examples include:

- **Planning project activities**. Project managers can allocate resources better and more cost-effectively if they know the exact location and full spatial extent of an intervention.
- **Planning site visits**. Field trips to project sites can be planned more strategically when the exact intervention sites are known. This helps to save time and prioritize visits to important sites.
- **Targeting**. Displaying baseline data on maps can provide information about potential beneficiaries and show where specific project interventions are already taking place, and where not, thus helping justify the selection of beneficiary communities, and identify potential gaps.
- **Understanding the intervention logic**. Many interventions have a spatial relationship and maps can show how these elements are connected. For example, rural roads should connect farmland to markets where farmers can sell their produce.
- **Measuring transects and areas**. GIS techniques can be used to accurately measure indicators with a spatial dimension (such as kilometres or hectares) in the "logical framework" – the basic document that guides the project's implementation. Once they are accurately measured, project implementers have the data to monitor progress and revise targets as necessary.

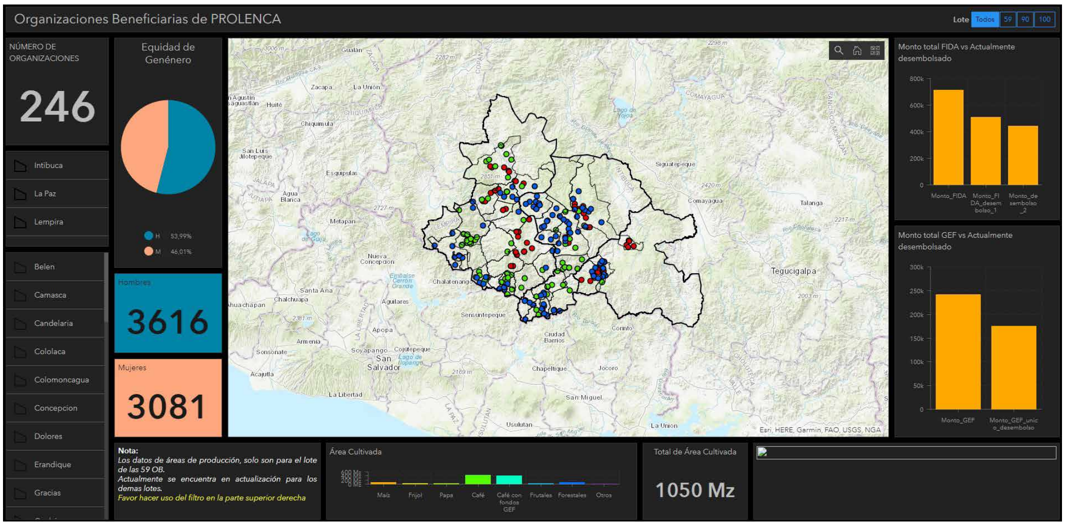

Figure 4. The online GIS dashboard of the [Project for Competitiveness and Sustainable Development in the South-Western Border Region] in Honduras helps the project team to keep track of the organizations the project is supporting, and it can be used as a tool for communication too.

- **Remote monitoring**. Knowing the boundaries of an irrigation scheme, for example, makes it possible to monitor changes in agricultural and land use via Earth observation. Detecting changes via satellite imagery is a cost-effective way to monitor large areas and multiple sites.
- **Identifying and mitigating risks**. Analysing the overlap or the proximity of project sites to legally protected areas (such as national parks), biodiversity hotspots and other areas of high environmental value can help the project to identify and mitigate risks of unintended adverse impacts.
- **Assessing impacts**. Good data are a precondition for any rigorous impact assessment. Geo-referenced monitoring is necessary to sample and match treatment and control sites, and control for confounding factors in order to identify impacts that can be attributed to the project.
- **Communicating**. Maps help to visualize plans and results: "a good map is worth a thousand words"! Many IFAD-funded projects started showing their data in online maps and dashboards.

Guidelines for IFAD-funded projects

IFAD's GeoM&E initiative aims to provide guidance to IFAD and the projects it funds to systematically collect GIS data for planning and M&E. A review of 60 IFAD-funded projects formulated guidelines covering the following components (see *Table 1*). Many of these suggestions are logical extensions of the procedures already followed in a well-functioning non-GIS M&E unit.

Expertise. Projects should employ a GIS specialist to support the M&E team. Field staff should be trained in how to collect and use GIS data.

Procedures. Each project should develop procedures detailing what GIS data to collect, how to collect and review it, how to store it, and how to use it.

Standards. GIS data must follow acceptable standards that are compatible with IFAD's central monitoring system. This makes it possible to aggregate data from across projects around the world.

Indicators. The indicators should be derived from the project's logical framework. Some of these indicators are standardized across IFAD projects worldwide – such as the number of kilometres of roads built.

Data collection. Data may be collected in various ways, including surveys, mapping missions, participatory mapping, and through service providers. For example, the locations of microcredit borrowers may be collected and uploaded automatically as part of a microfinance project. Other data may be derived from external sources, such as satellite imagery or national statistical agencies.

Software. In most cases, it will be necessary to use a variety of software applications to collect and analyse the data. Google Earth is good for portraying data in a user-friendly format, for example, but it is difficult to tag points with other attributes (such as cost, implementation status or duration), which may be important for monitoring. It will be necessary to manage the data in a different software package for it to be useful for monitoring purposes.

Hardware. Field staff may need to be equipped with (and be trained in using) tablets, GPS devices, etc. This hardware will need to be equipped with the appropriate software – perhaps adapted for the project's needs.

Reporting. Procedures should ensure that the data are collected on a regular basis to allow project managers and IFAD to monitor the project in real time. Standard templates will be needed for reporting the information in a consistent and communicative way.

Dos and don'ts

- Ideally, integrate GIS to support monitoring and evaluation **from the start** of the project. Make sure to include GIS activities and funding for these. The costs of georeferencing investment sites should be part of the project's M&E budget.
- **Start with the end in mind**. Projects need to measure the impact that can be attributed to its activities. GIS can help with planning, targeting, and identifying control (or comparison) and treatment (or beneficiary) groups.
- For ongoing projects, it is feasible to incorporate GIS into its monitoring and evaluation systems. A **capacity assessment** should be conducted to bring insights on what can be done.
- **Do not collect GIS data for everything**. Collecting GPS coordinates has a cost. The project has to reflect where it makes sense to collect data and how the data is to be used.
- There is **no one-solution-fits-all**. Projects should choose what software solutions and data-collection procedures suit their situation best. Nonetheless, established data and metadata standards as well as best-practice procedures should be adhered to.
- **Gender** and other socio-economic factors can be mapped, as geo-referenced data can be gender-disaggregated (e.g. female-headed businesses, groups or households).
- Data collection should conform to **privacy rules** in the host country and at IFAD. Personal data must be protected (for example through anonymization) to maintain the privacy of project beneficiaries. The data must be secured to prevent unauthorized access and **stored in a secure way** to avoid accidental loss (for example if a computer breaks down).
- **Service providers** (e.g. companies designing irrigation schemes) are important data sources as they can collect GIS data and then forward it to the project teams. It is best to include terms in the project **procurement** documents specifying that GIS data is to be collected and submitted to the project teams.
- IFAD's **Social, Environmental and Climate Assessment Procedures** (SECAP) require projects to map the locations and geographic extent of investments that might adversely affect people and the environment.

Table 1. Minimum requirements for an IFAD-funded project in mapping investment sites

Area	Requirements
Expertise	• One GIS expert to support the monitoring and evaluation team • Field staff trained to collect GIS data
Procedures	• Operational guidelines explaining what data is collected, how it is collected, reviewed, stored and used
Standards	• Metadata (rules that describe data) • Format: shapefile vector format • Attribute table: standard fields for each indicator to record type of activity, status of activity or date of completion
Indicators	Indicators of the logical framework measured with GIS, e.g.: • Rural roads constructed or rehabilitated • Irrigated farmland • Land area under improved management • Infrastructure such as markets, processing and storage facilities • Rural institutions and businesses.
Data collection	• Surveys of households, businesses/producer organisations, and communities • As part of regular monitoring and evaluation activities • Standalone mapping missions e.g. of farmland and roads • Service providers
Software	In most cases a combination of different programmes to: • Collect data (KoBo Toolbox or SurveySolutions) • Data-handling software (such as QGIS or ArcGIS) • GIS platform to store and visualize data
Hardware	• Smartphones • GPS devices (e.g. a medium-sized project might require 20-30 GPS devices) • Drones
Reporting	• Reporting to IFAD once per year before project visits following standardized methodology

Getting support

The GeoM&E initiative has drafted further guidance documents for project planners and managers. These include:

- How-to guide: Mapping IFAD investments;
- Guidance materials such as presentations;
- Sample geospatial data standards for projects and quality checklists;
- Standard terms of reference for consultants monitoring IFAD-funded projects and project staff implementing GIS-supported monitoring and evaluation;
- Cost estimates; and
- Sample data sets on monitoring and evaluation.

Contact the focal points for more information.


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D. CASE STUDIES

Rural development projects in Latin America

Targeting the poor and people vulnerable to climate change

In rural development, it is important to **target the right areas and the neediest communities**. Spatial analysis can be very helpful to do this. The designers of IFAD-funded projects in Argentina, Honduras, Nicaragua and Peru **used simple GIS techniques** to overlay climate risks and impacts onto maps of the project country. This information was used to help decide the location of project activities.

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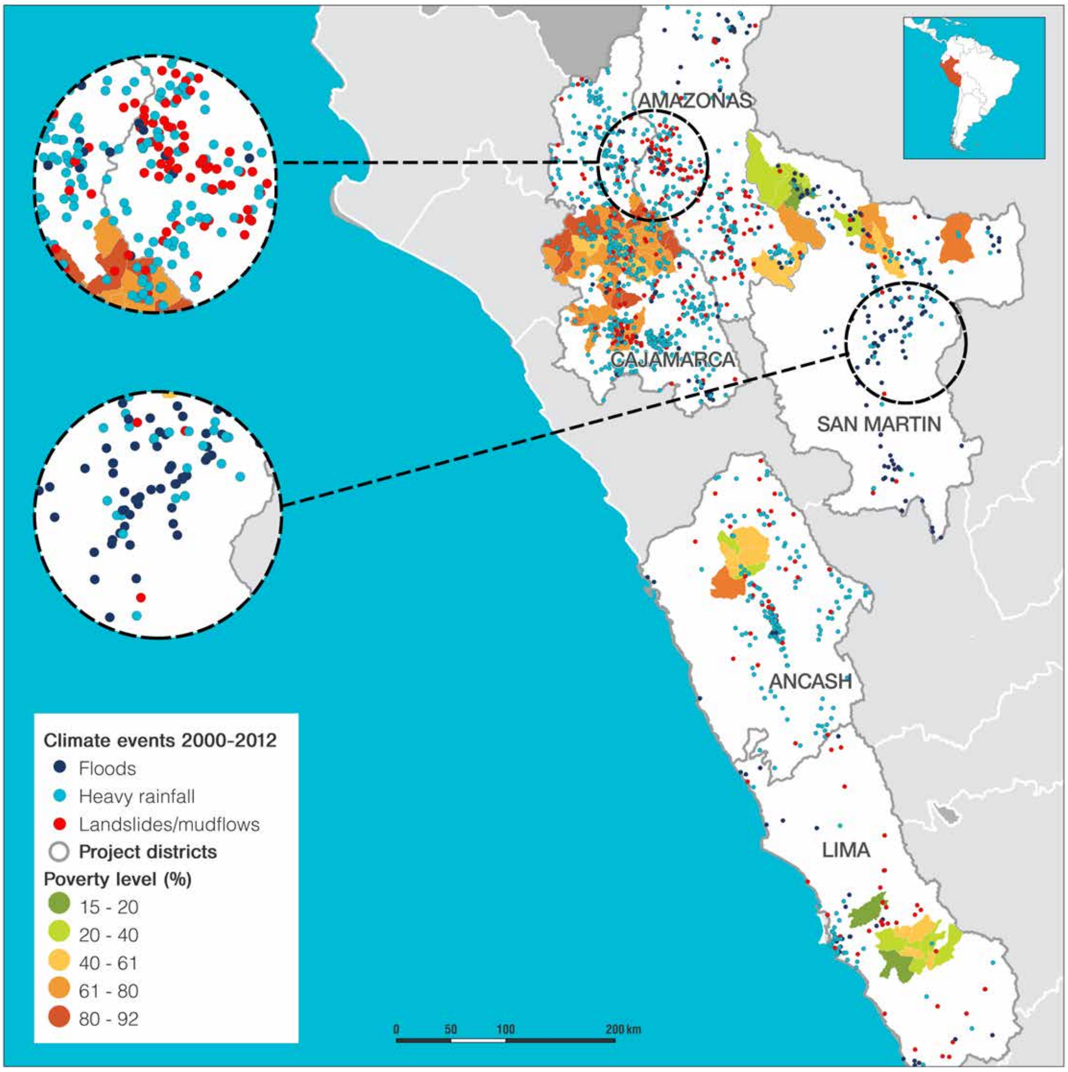

Figure 1. Peru: The map shows poverty in selected districts and extreme climate events (floods, heavy rainfall, landslides/mudflows) from 2000 to 2012 in the project area of Avanzar Rural. The top highlighted area shows an example where landslide protection is needed. The area below shows a location where flood control should be prioritized.

Author: Oliver Mundy | Design: Tuuli Sauren | Maps: Rakhat Zhanuzakova | Editing: John Laird

A major challenge in using GIS to target project interventions is getting **reliable, up-to-date data**. Good data often exists but is not publicly available. The project design teams approached various public entities (including at the municipality level) to obtain relevant data that would be acceptable to government decision-makers.

> **The design teams managed to get hold of data on exposed rural populations, poverty levels, areas of river and flash flooding, areas impacted by hurricanes, drought-prone areas, etc.**

The teams used **free, open-source GIS software** to create thematic maps. They weighted and aggregated spatial data to prioritize intervention areas. The selection of vulnerable areas was based on criteria (listed in *table 1*) from **IFAD's targeting policy and guidelines**, as well as the country's own priorities.

This targeting approach has also been part of IFAD-supported proposals to global climate-related funds such as the Green Climate Fund and the Global Agriculture and Food Security Program.

Table 1. Targeting criteria to select intervention areas

Criteria	Priority
Extent and intensity of poverty	Highest ↑
Nutritional and food insecurity	High ↗
Environmental degradation and climate vulnerability	Medium →
Presence of indigenous peoples, tribal and ethic minorities	Medium →
Number of young people	Medium →
Presence and number of fragile or marginalised groups	Medium →
Productive and geographical potential	Medium to low ↘

Argentina

In the design phase of past IFAD interventions in Argentina, IFAD teams have faced difficulties in measuring levels of acute poverty and climate vulnerability. As a result, some areas that needed support were omitted from the projects.

However, during the design phase of the recently approved PROSAF project, which promotes sustainable family farming, the design team obtained geospatial data on poverty, food security, drought and flood risk, presence of indigenous communities and coverage of internet services at the village level to assess the situation in potential areas. As a result, the **final project area was extended to provinces that had not been deemed eligible in previous projects**.

Peru

The Avanzar Rural project supports small-scale farmers and rural enterprises in selected highland and rainforest areas of Peru. The design team used **GIS data on the occurrence of floods, heavy rainfall and landslides/mudflows** (as in *figure 1.*) to decide where the project would intervene, and what activities to undertake to manage disaster risks and help local people adapt to climate change.

Honduras

The INNOVASAN project aims to promote sustainable **food systems**. The government of Honduras and IFAD agreed to intervene in areas that are prone to climate change. They selected the target areas by using data from two recent events – **tropical storm Eta and hurricane Iota** – which caused immense damage in November 2020. The design team produced maps, such as in *figure 2*, showing levels of loss and damage in agriculture, municipalities that were most affected by floods, and areas subject to food insecurity and crisis during the storms' aftermath.

RESOURCES

Webinar

Figure 2. Honduras: Levels of damage in agriculture caused by tropical storm Eta and hurricane Iota in November 2020. Areas shaded orange and red were the areas most badly hit.

Figure 3. Climate hazards in Nicaragua.

Nicaragua

The Nicapesca project aims to support value chains in artisanal fishery and aquaculture on the Caribbean coast of Nicaragua. Initially, the Government of Nicaragua and IFAD expected to focus the project in the northern coastal region; but after GIS data revealed that **both northern and southern areas were equally vulnerable to climate events** (see areas in red on *figure 3.*) the project area was enlarged to encompass both areas. The criteria used to select the project areas included fishing communities within 5 kilometres of major inland water bodies that are exposed to floods, municipalities highly exposed to hurricanes, coastal flooding and flash floods, and the presence of vulnerable communities (indigenous people or undernourished populations).

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Assessing climate vulnerability in rural development projects

Climate change threatens the resource base of the rural poor. It leads to soil erosion, more frequent flooding and longer dry spells. Many pastures and forests are not well managed, and climate change exacerbates their degradation. IFAD uses GIS to **identify areas where a change to more sustainable and climate-resilient practices are needed.** This case study presents examples of how spatial analysis has been used to target poor and vulnerable areas in the design of IFAD-funded projects in the Republic of Moldova, Morocco, Tajikistan and Tunisia.

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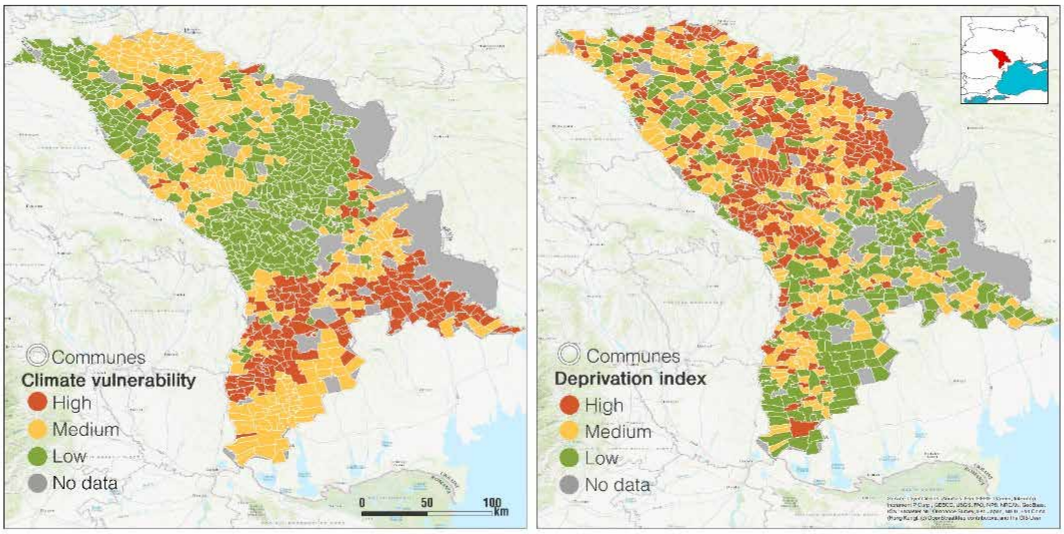

Figure 1. Climate vulnerability (left) and deprivation index (right) showing the level of development of communes in the Republic of Moldova.

Environmental and climate specialists at IFAD need to identify areas where climate change is likely to create the most serious problems and where **interventions are most urgently needed**. But climate change is not the only factor that project planners must consider. They must also factor in **social, economic and other variables**. The specialists use free, open-source GIS software to create indices and maps that combine these various factors and guide where projects should invest their limited resources.

A **robust analysis of climate vulnerability** is also necessary to attract additional support from funds such as the Green Climate Fund and the Adaptation Fund, which support countries to adapt to the effects of climate change. These funds demand a rigorous analysis before they will consider providing support.

Project designers should consider the following when deciding whether to conduct geospatial analysis for targeting climate-vulnerable areas:

- **GIS expertise**. Ideally, a member of the project design team should have the skills to conduct the analysis.
- **Planning**. The analysis, map creation and presentation to stakeholders should be planned from the start. The geospatial analysis must be seen as an integral part of the design and decision-making process.
- **Government engagement**. Government agencies should provide input on the types of data and the data sources to be used and the agree on the methodology that should be applied. They should give feedback on the analysis and the maps.

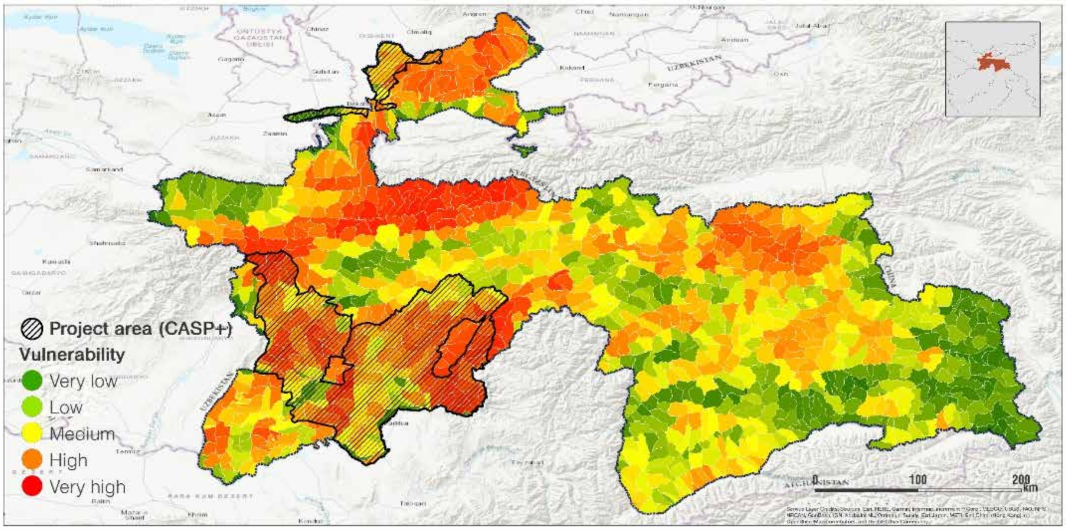

Figure 2. Climate vulnerability of watersheds in Tajikistan.

- **Data**. A huge amount of data is freely available: it includes satellite imagery, elevation models, maps detailing types of land cover, and climatic data. Design teams should also request government agencies for data, as they often hold interesting datasets from other projects and organizations.

Targeting climate-vulnerable and poor households in the Republic of Moldova

The Talent Retention for Rural Transformation project, or TRTP, supports smallholder farmers and young entrepreneurs in the Republic of Moldova to modernize and commercialize their businesses, while ensuring they are adapting to the effects of climate change. The project design team produced two maps – both shown in *figure 1* – to help the project identify the municipalities most in need. The map on the left depicts climate vulnerability and is based on data from the Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS) for the period of 1981-2018. The map shows a composite index made up of three parameters:

- **Annual rainfall** – drier areas are more vulnerable to dry spells.
- **Heavy rainfall** – areas with daily heavy rainfall events have a higher risk of crop damage, soil erosion and flooding.
- **Becoming drier** – areas receiving less rainfall over time are more vulnerable to dry spells.

The second map, on the right, shows the development level of a local community using the Small Area Deprivation Index (SADI). This composite indicator combines 7 sets of indicators related to economic development, access to education and infrastructure facilities, healthcare and the extent to which local public budgets can afford community development and support to vulnerable groups of population.

Both maps **guide the project in deciding where to concentrate support** – such as irrigation development, the construction of rural roads and business grants – for it to benefit small businesses in an effective way. Some of the flagged areas were not in the focus of previous IFAD-funded projects in the country.

Climate vulnerability analysis of Tajikistan

The new Community-based Agricultural Support Project Plus, or CASP+, will support rural communities in Tajikistan to better manage and derive income from natural resources such as pastures and forests. The Government of Tajikistan and IFAD agreed to intervene in areas that are vulnerable to climate change, and to attract additional funding from the Green Climate Fund. The project design team applied the **GeoAdapt tool** to compute a compound index to classify districts and watersheds by their vulnerability to climate change. The resulting **maps were an integral part of project design**. The analysis used the following climatic and socio-economic variables:

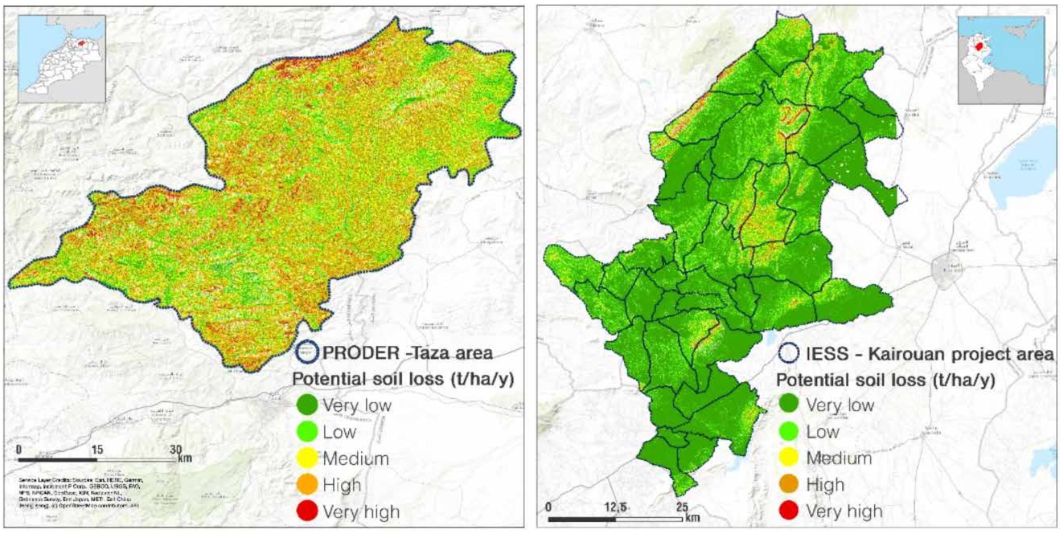

Figure 3. Soil erosion maps for the project area of PRODER-TAZA in Morocco (left) and the IESS-Kairouan project in Tunisia.

Exposure

- Summer rainfall significant trend (Source: CHIRPS for the period 1981-2019)
- Daily heavy rains (number of events >10mm/d (CHIRPS for the period 1981-2019)
- Standardized Precipitation Evapo-transpiration Index (SPEI) – an index for measuring droughts – average and trend for 1981-2019 (Terraclimate)
- Maximum temperature trend for 1958-2019 (Climatic Research Unit, University of East Anglia, TS v4.05)

Sensitivity

- Erosion RUSLE 2015-2019 computed by the Climate Resilience Cluster of the Earth Observation for Sustainable Development (EO4SD) programme
- Degradation of rangelands and forests (MODIS vegetation indices 2005-2020)
- Rural population (Worldpop)
- Poverty rate (%) (National data)

Adaptive capacity

- Access to irrigation (CCI/ESA, 2019)
- Proximity to main roads (Global Roads Open Access Data Set, v1.0)
- Youth population <35 years old (Worldpop)

The final map (*figure 2*) shows that rural mountainous areas in which agroforestry and livestock-keeping are the main livelihoods are the most vulnerable. The communities in these areas have a lower quality of life (e.g. less access to water, electricity and markets) and lower incomes than people elsewhere in the country. The maps were presented and discussed on various occasions with the Government and other stakeholders. They were the basis for deciding that the project will intervene in the most vulnerable districts not currently served by other climate-related projects.

Erosion modelling in Morocco and Tunisia

The PRODER-TAZA project in Morocco and the IESS-Kairouan project in Tunisia both support poor, rural households in hilly and mountainous areas. The Moroccan project supports small producers of almonds, figs, olives and honey. The Tunisan project sets a strong focus on training farmers on topics such as business skills, nutrition and financial literacy. Soil erosion is a major environmental problem in both project areas. The project design teams created maps using the Revised Universal Soil Loss Equation (RUSLE) model to show **areas vulnerable to soil erosion due to heavy rain and storms** and to draw budgets on specific activities to reduce their impact on rural population. Highly vulnerable areas are likely to be more affected by climate change. The analysis will be repeated during project implementation with up-to-date satellite imagery. The maps help the project to define where activities on erosion reduction and control are likely to have the greatest effect.

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Designing a rural development project in Yemen

Overcoming COVID-19 and conflict constraints using GIS

Geospatial analysis made it possible to design a new rural development project in Yemen at a time when it was not feasible to visit the country because of COVID-19 and security issues. The geospatial assessment identified intervention areas and preliminary response options for the Rural Livelihood Development Project (RLDP), an initiative to improve the livelihoods of 26,000 poor households by increasing their agricultural production and building their resilience to climate change.

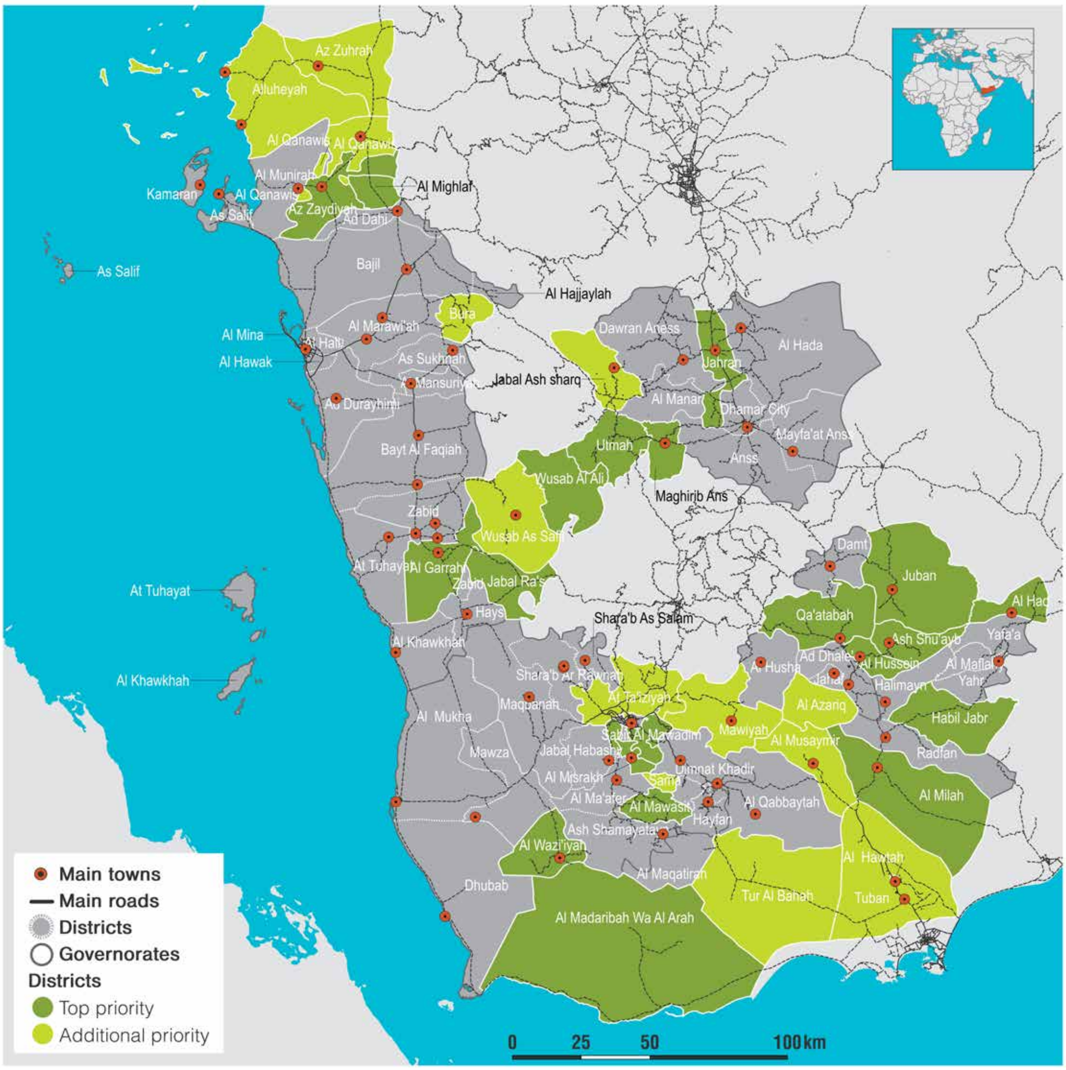

Figure 1. Priority districts of the Rural Livelihood Development Project.

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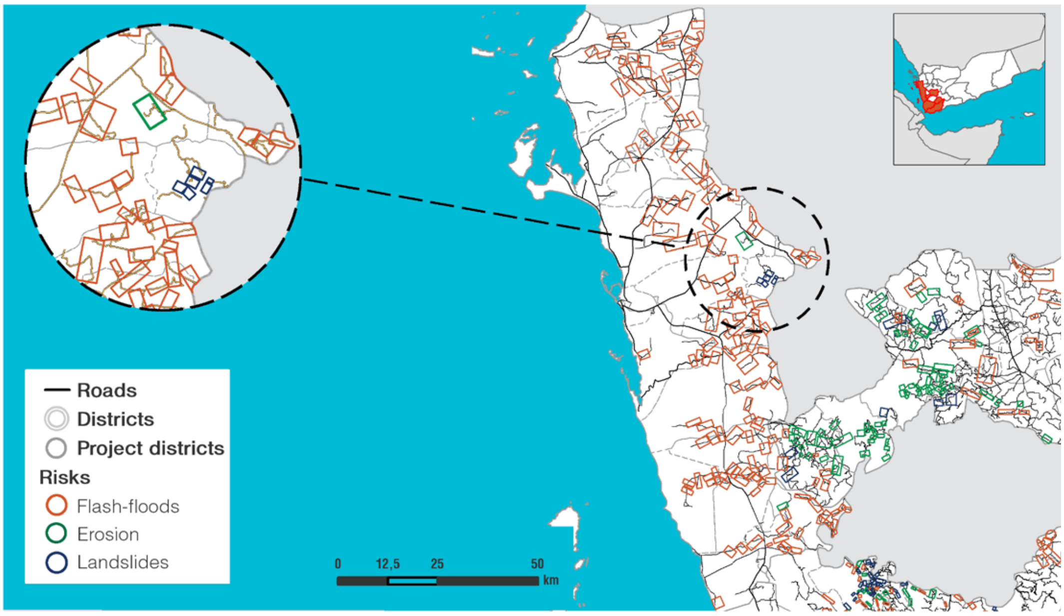

Figure 2. Response analysis for climate-resilience interventions suggests locations for measures to control and prevent flash floods, erosion and landslides.

Yemen, one of the Arab world's poorest countries, has been in a state of civil war since 2014. The conflict has had devastating effects on the rural population, which faces acute food insecurity and extreme poverty.

The RLDP, a US$20 million project funded by IFAD and the Global Environment Facility, was designed in March and April 2020, at the height of the COVID-19 pandemic. **Travel at this time was impossible**. International staff and local experts had to design the project without visiting the field or meeting beneficiaries. The project design relied heavily on the analysis of spatial information and Earth observation data to identify the most vulnerable districts and villages to intervene in and to prioritize the intervention options.

The IFAD design team was supported by the Food and Agriculture Organization of the United Nations (FAO) Country Office, the Yemen Social Fund for Development, and an experienced national consultant who had **"ears on the ground"**. Geospatial analysis expertise was provided by the World Food Programme (WFP) through the IFAD-WFP Joint Climate Analysis Partnership that has been supporting IFAD operations since 2014.

Three **risk indices** were calculated to help with selection of intervention areas using the following spatial datasets:

- **Climate risk:** Rainfall variability and trend, dry-spell trend, maximum and minimum temperature trend;
- **Environmental risk:** Erosion, flooding and landslides;
- **Nutrition vulnerability** e.g.: from the Integrated Food Security Phase Classification (IPC) and Global Acute Malnutrition measure.

The risk indices were combined into a map showing **priority districts** (see *figure 1*) and a long list of 34 potential districts. The selection of districts also considered population density, previous investments by IFAD, the current security situation, and the presence of other agency programmes. Having a long list of districts gives the project flexibility in case the security situation changes and the focus has to be set on other districts. The final selection of districts was undertaken by the IFAD design team and the FAO Country Office.

Geospatial analysis was also used to identify the appropriate **climate-resilience measures** for over 4,000 villages. These were grouped into village units, each containing around four villages or around 100,000 inhabitants. GIS analysis and maps (see *figure 2*) suggested where to promote small-scale irrigation schemes and flood-based agriculture in order to mitigate flash floods, and where the project should focus on soil and water conservation measures to prevent soil erosion and landslides.

From assessment to action on climate adaptation

Building resilience through community watershed management in Nepal

Drought, erratic and heavy rainfall, flooding and landslides are common in many parts of Nepal. Climate change is intensifying these hazards and undermining the livelihoods of local communities. For instance, despite higher annual rainfall in certain areas, less water is available because intense rainfall causes heavy runoff – this means that soils do not absorb the rainfall and recharge groundwater levels. The IFAD-funded Adaptation for Smallholders in Hilly Areas Project (ASHA) is helping rural communities to develop and implement Local Adaptation Plans of Action. These plans combine scientific and community knowledge with **GIS-based sub-watershed-level assessments** to determine the extent and location of measures such as **afforestation, landslide protection or erosion** control that help communities adapt to the effects of climate change.

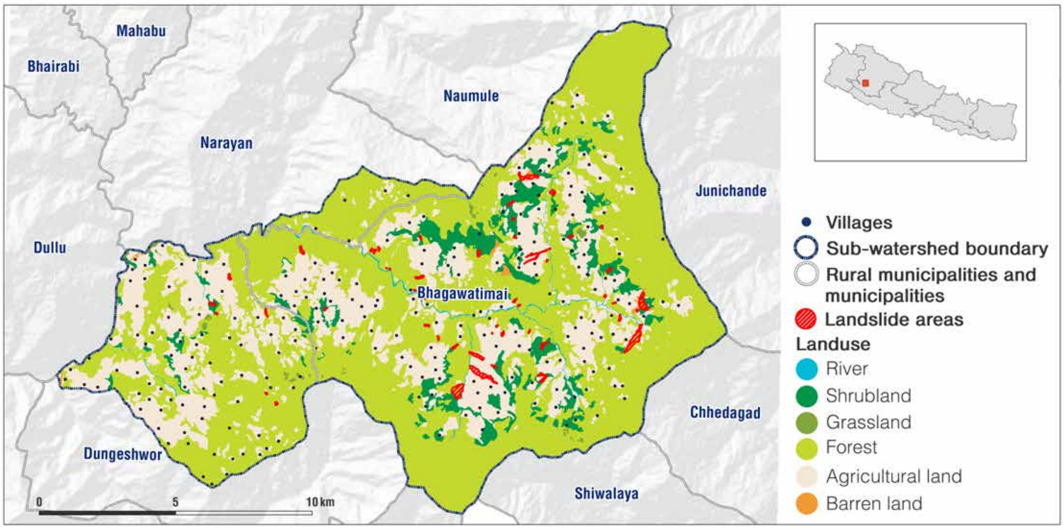

Figure 1. Land use and land cover of Katti sub-watershed.

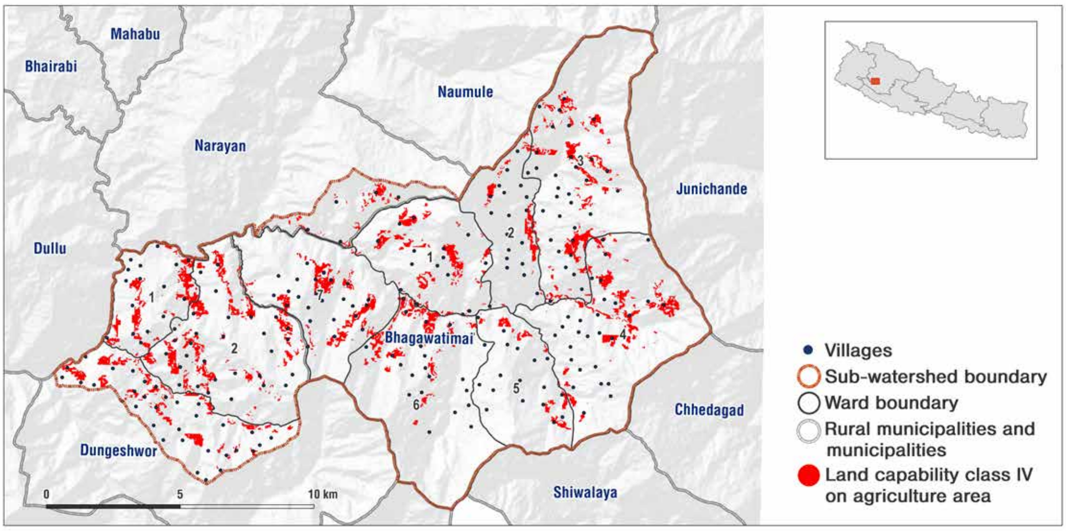

Figure 2. Agricultural land recommended for adjustment (e.g. terracing needed because of steepness or more suitable for forests) in the Katti sub-watershed.

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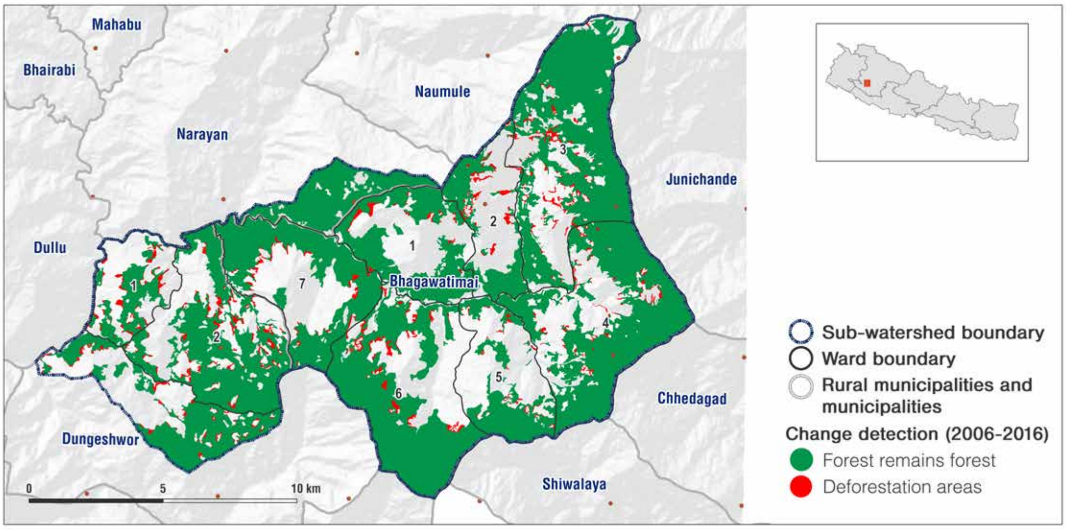

Figure 3. Location of forests and deforested areas in the Katti sub-watershed.

The Local Adaptation Plans of Action, abbreviated as LAPAs, help communities understand how current and future climate change affects their livelihoods and what measures are necessary to adapt to those changes. They detail what is needed to improve land management at a sub-watershed level (i.e. an area of land connected through waterways and a common drainage system) to build landscape level resilience to climate hazards. The adaptation plans detail a mix of "hard" measures (i.e. infrastructure and earthen works) and "soft" measures such as better community organization through formation of permaculture producer groups.

ASHA has developed and helped communities implement adaptation plans for thirty sub-watersheds in seven districts of the Karnali and Lumbini provinces of Nepal. The plans lay out adaptation measures for 200 wards under 30 municipalities. The measures to help cope with climate change include:

- **Reforestation and forest management**. Tree plantings, nurseries for multipurpose trees, forest fire control, invasive species management, and preparing community plans on how to protect soil and use forests for timber, fuel and food in a sustainable manner.
- **Erosion-control measures**. Terracing, water runoff control, gully treatment, water source protection that control the flow of water and reduce the amount of soil being washed out.
- **Landslide protection**. Check dams, retaining walls, constructing of ponds to store and divert excess runoff, permaculture, selecting plant species that hold soil well, and discouraging growing crops on steep slopes to reduce the risk of landslides.
- **Environment-friendly technologies**. Installing renewable energy technologies such as solar home systems, solar water-lifting systems, and fuel-efficient cooking stoves, allowing villagers to collect less fuelwood from forests and reducing their exposure to harmful smoke.

The adaptation plans bring together **scientific analysis (top-down) and community knowledge (bottom-up)**. Under the facilitation of ASHA project staff, communities and other important stakeholders such as local non-governmental organisations develop the plans together with planning experts. **Participatory methods** allow community members to help formulate the plans. The community members check the findings of the analysis, correct them if necessary, and add detail. The project then helps the communities implement their plans through training, building infrastructure and other means.

RESOURCES

ASHA project webpage

Local Adaptation Plan for Action Manual

GIS assessment of the Katti sub-watershed

Local Adaptation Plans of Action go through a seven-step process:

1. **GIS-based sub-watershed assessment**. Prior to engaging with communities, GIS experts conduct a series of environmental assessments to create maps of land use, soil erosion, fires and other topics with upstream and downstream linkages (see *table 1*).
2. **Climate change sensitization**. Project staff mobilize communities to take part in the planning process. They meet and discuss the impacts of climate change and start exploring options for how to cope with it.
3. **Vulnerability assessment**. The communities identify the main hazards they face, map their resources, explore linkages between sub-watersheds, and discuss how climate change affects them. Project staff organize a series of workshops at different levels (settlement, ward and district) to discuss the findings of the GIS assessments.
4. **Prioritization of adaptation options**. This step is carried out jointly with the previous step. Communities identify the most important measures to be implemented.
5. **Formulation of adaptation plans**. Plans are laid out specifying the type and place of interventions, the entity carrying them out, and the cost of the measures.
6. **Integration of the adaptation plan into the municipality development plans**. The plan is included in the district planning to ensure that activities are aligned with other government activities and efforts are not duplicated.
7. **Implementing the plan**. ASHA project teams equip communities with the necessary resources to carry out the activities laid out in the plans in collaboration with the relevant stakeholders.
8. **Process assessment**. ASHA project staff capture feedback and lessons on how the plans were implemented, and make recommendations to improve the planning.

Table 1. Local Adaptation Plans of Action can feature a wide range of maps. Here some examples

This map …	… helps to do this
Land-use change	Identify areas where change is the greatest, e.g. due to the effects of climate change and population pressure and where support might be most needed.
Forest degradation and deforestation	Identify hotspots of deforestation and select areas for improved forest management and conservation.
Drought	Identify areas most affected by dry spells in which water conservation measures are needed most.
Community forests	Understand how much forest is under community tenure and plan for improved forest management.
Soil erosion	Identify locations for soil conservation measures.
Waterways and springs	Locate riverbanks and water sources that need protection (e.g. from erosion caused by heavy rainfall events) and can be exploited for domestic use and irrigation.
Landslide susceptibility	Identify locations for landslide-prevention measures.
Land-use adjustments	Identify areas where the current land use is inappropriate (e.g., crop farming on steep slopes) and benefit from e.g. terracing or afforestation.
Forest fires	Identify major forest fire hotspots, fire risk zones and preventive measures e.g. firelines construction, tending operations to help reduce forest fire risk.
Population density	Understand where measures could benefit the most people.
Ethnic composition	Take into account the cultural norms of the residing population (e.g. language, religion, festive days, etc.).
Economic active population	Help understand how community members can contribute to an activity (e.g. poor farmers can provide labour but no financial contributions).

The project has engaged over 116,900 people through this process.

Nearly 79,300 households are benefiting from the measures laid out in the land use plans.

Approximately three-quarters of the funding for adaptation measures comes from IFAD, while municipal budgets make up the shortfall. This ensures that municipalities take ownership of the adaptation activities and reorient municipal spending towards climate change adaptation. IFAD also provides additional finances for measures that go beyond the administrative boundaries of a municipality to incentivize landscape level interventions.

The rigorous community engagement ensures that **communities take ownership** of the process and activities, making it more likely that communities will continue to benefit from the measures after the project ends.

The project further refined the methodology and updated its planning manual in 2018 (see Resources). These guidelines are officially recognized by the Government of Nepal.

ASHA teams also **map the sites where measures are carried out** to keep track of the progress the project is making. The GIS data are stored in an online monitoring and evaluation system.

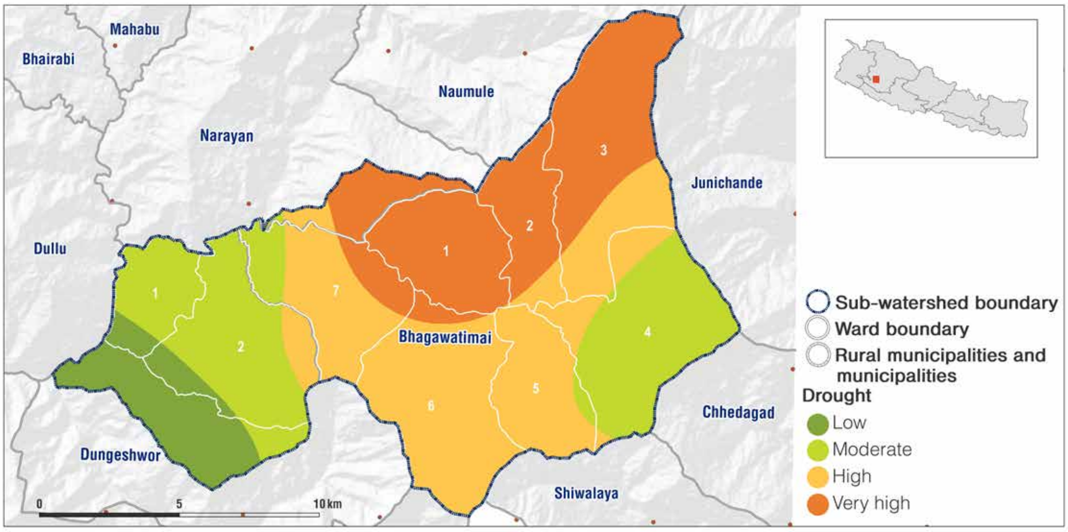

Figure 4. Drought risk in the Katti sub-watershed.

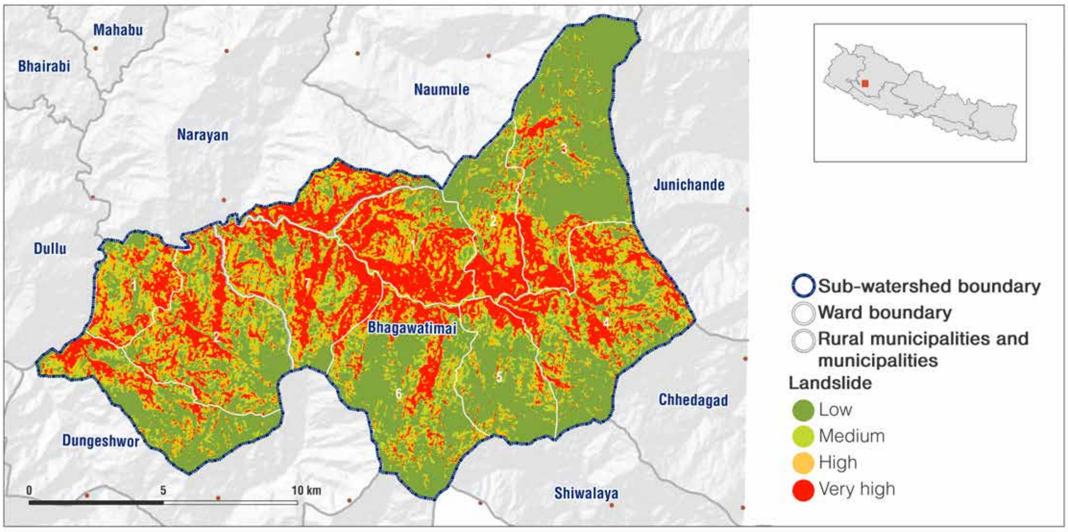

Figure 5. Landslide susceptibility in the Katti sub-watershed.

Author: Oliver Mundy | Design: Tuuli Sauren | Maps: Rakhat Zhanuzakova | Editing: John Laird

Combining field data and satellite imagery

A dashboard to monitor rangeland health in Lesotho

Lesotho is a mountainous country that suffers from severe erosion and soil degradation. Once a food basket for southern Africa, the country has been dependent on food aid for decades. The Lesotho Rangeland Health Dashboard, developed by the World Agroforestry Centre (ICRAF), is a tool to improve the management of the rangelands that cover 60% of the country.

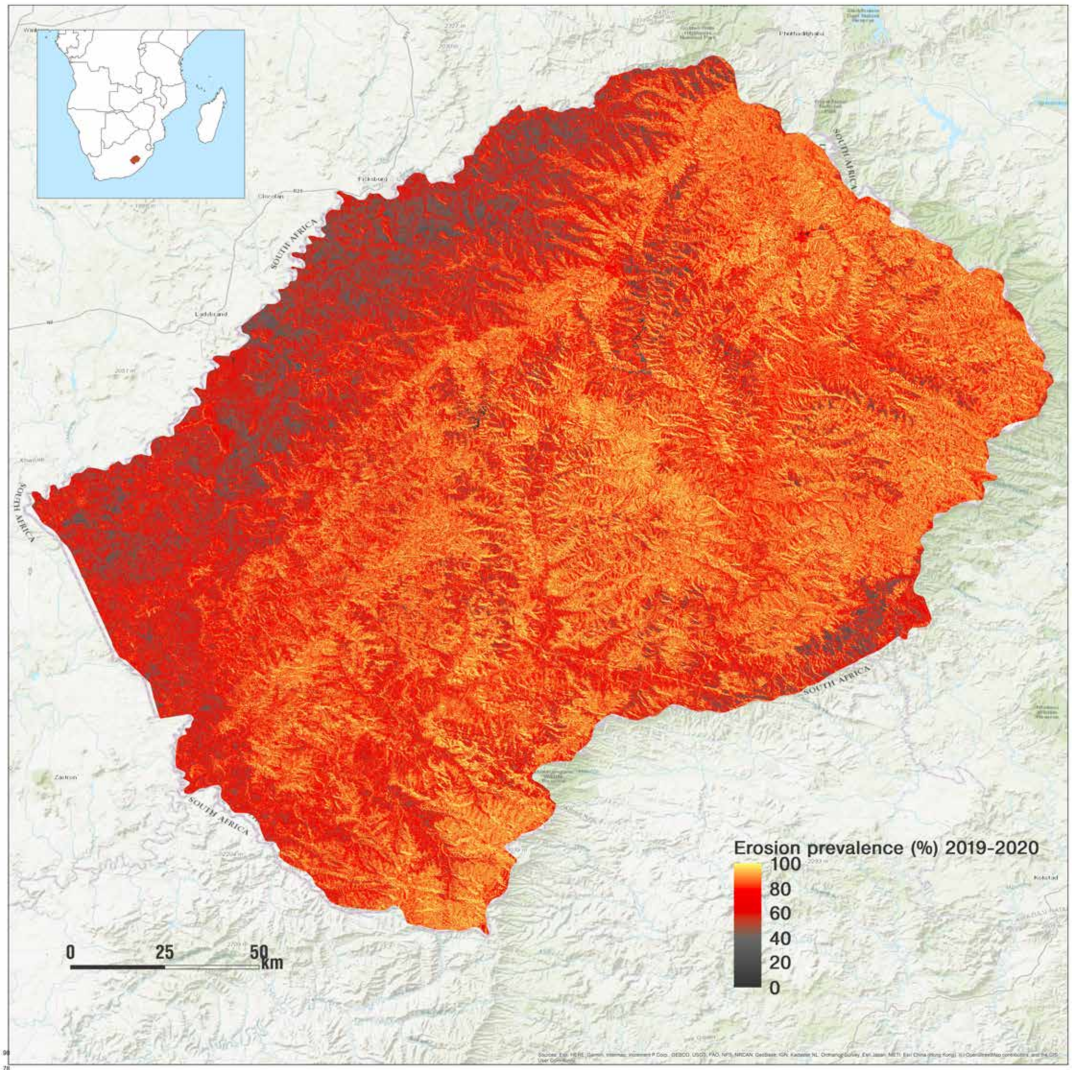

Figure 1. The map on soil erosion prevalence in Lesotho shows that the majority of the country is impacted by severe erosion.

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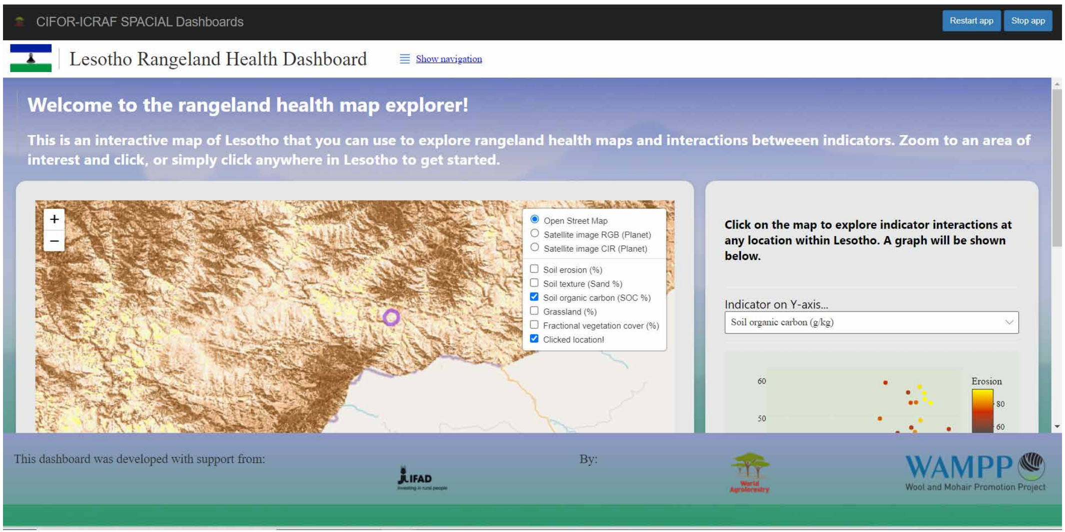

Figure 2. The Lesotho Rangeland Health Dashboard holds five indicator maps on rangeland health. Users can generate graphs by clicking on a location.

Very little is known about the state of ecosystems across Africa. Lesotho is an example: erosion is severe, huge areas are degraded, and the changing climate is shifting rainfall patterns. But the precise situation in each location is uncertain. That makes it hard to design interventions to tackle the problem through improved land management.

Much of Lesotho is rangeland that is continually grazed and poorly managed. That strips the soil of vegetation and exposes it to erosion. Heavy summer rains wash the soil away, and gullies eat into pasture and cropland alike. Climate change means that the amount and quality of grazing are declining.

The IFAD-funded Wool and Mohair Promotion Project (WAMPP) aims to improve rangeland management in Lesotho. As part of this, the ICRAF has developed an approach to **assess and monitor rangeland health**. This consists of three components:

- **A manual on climate-smart rangeland management**, aimed at trainers who will go on to train herders. This was developed with the National University of Lesotho.
- **Capacity building** of local staff in remote sensing, the collection of field data and data analytics.
- **Data collection, analysis and visualization** on rangeland health. This included field data collection for ground-truthing, as well as remote sensing data of the whole country from Landsat satellites. This is brought together in an interactive "dashboard".

Collecting field data

The project uses data from three main sources. One of these is remote-sensing data from Landsat, which covers the entire country. But it is necessary to "ground truth" the satellite data – to check the situation on the ground to make it possible to interpret the satellite imagery correctly. The project gathered this ground data in two ways.

The first was a network of 10 field locations scattered around the country, where the project field staff gathered data using ICRAF's Land Degradation Surveillance Framework. Each location measured 10 km^2. Within each one, they selected 10 plots (100 m^2) at random, and 4 subplots (10 m^2) within each of these. For each subplot, the staff:

- **Geo-referenced** and photographed the subplot;
- Described its **site features** (e.g. if it is on a slope);
- Determined if **erosion** is occurring;
- Measured the **scrub and trees densities**;
- Measured the **soil infiltration capacity**;

RESOURCES

Dashboard

Curriculum on climate-smart rangelands

Co-designing decision dashboards

Predicting soil erosion with remote sensing

Land Degradation Surveillance Framework

- Collected **soil samples** for laboratory analysis to determine soil organic carbon; and
- Listed and counted all plant species to measure **biodiversity**.

The second was a network of 45 sites from Lesotho's annual rangeland health assessment, managed by the Government's Department of Range Resources Management. This gathers information each year on plant diversity and density, land cover and other indicators.

Machine learning

The project combined these field measurements and satellite imagery to **compute rangeland health indicators** for the entire country at 30 m resolution. It used machine learning techniques to train models to do this. These extrapolate from the satellite imagery to predict the most likely rangeland conditions at each site.

Lesotho Rangeland Health Dashboard

The final results are displayed in an online web-platform. The dashboard is based on R Shiny, an open source software. It was designed in a workshop with key stakeholders. The dashboard contains the following **indicator maps on rangeland health**:

- **Soil erosion prevalence** helps identify soil erosion hotspots;
- **Soil organic carbon** gives information on the capacity of the soil to absorb and hold water, the erosivity of the soil and soil biodiversity;
- **Soil texture** (% sand) gives information on the soil's water-holding capacity, the infiltration rate, and the soil's potential to store organic carbon;
- **Grassland** shows where grasslands are located; and
- **Fractional vegetation cover** shows how much vegetation covers the ground.

How to use the information

Indicator maps can help WAMPP and other projects identify locations for investments to restore rangelands, and to monitor the success of such interventions.


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Pasture mapping and assessment

Strengthening pastoral and herder resilience in Kyrgyzstan

Kyrgyzstan is a livestock country. A large part of its land area serves as pasture for around 1.7 million cattle and 6.3 million sheep and goats. However, many pastures are overgrazed and climate change adds further pressure on this vital resource. IFAD-funded programmes are using GIS technology and analysis to help rural communities in Kyrgyzstan manage their pastures more sustainably and adapt to the effects of climate change.

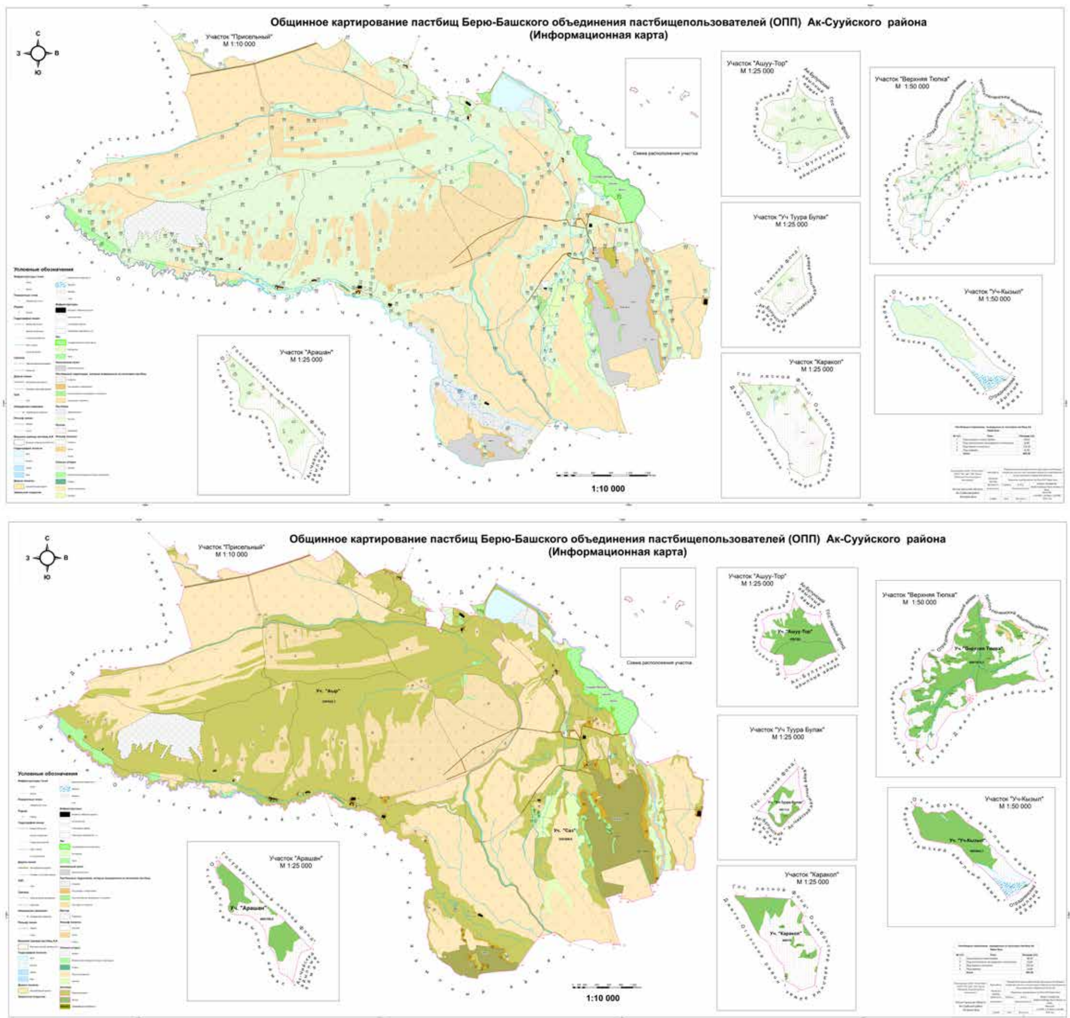

Figure 1: General map (top) and pasture boundary map (bottom) of the Beryu-Bash Municipality showing pasture boundaries, land use and infrastructure locations.

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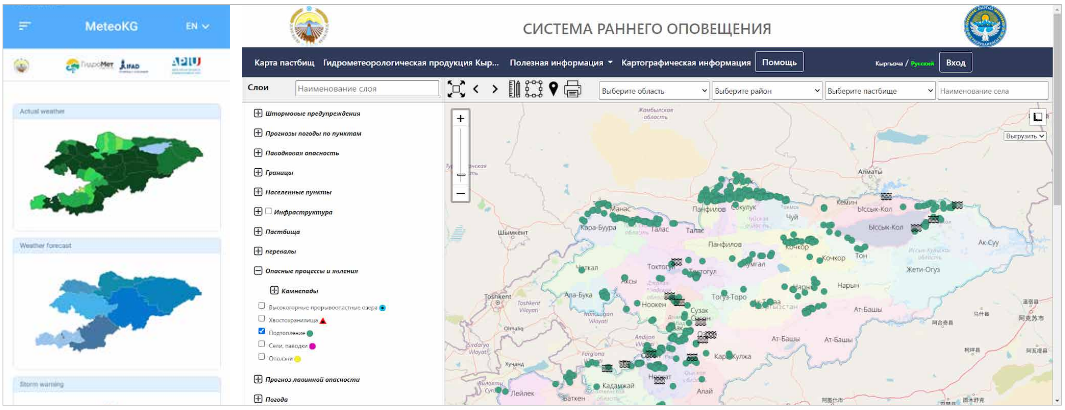

Figure 2. Screenshots of the mobile application (left) and the web-platform.

Pastoral systems, if well managed, are the **best-suited and adaptive form of agriculture** for the majority of Kyrgyzstan's land area that is too dry, cold, or mountainous for crop farming. Herders are very mobile: they use the entire landscape, from the winter pastures in the valleys to the high summer pastures. Such mobility also allows them to respond to extreme weather events such as drought or heavy snowfall. Measures that strengthen the pastoral system also strengthen its capability to respond to climatic shocks.

Every livestock owner in Kyrgyzstan belongs to a **pasture user union**. They are represented by an elected committee. Every municipality has a union. By law, the unions have the tenure rights over pasture areas. This means they can develop land (building infrastructure such as water points), derive income from it (via raising usage fees and renting it out) and ensure its sustainable use (e.g. by establishing appropriate stocking rates and applying no-grazing areas on highly degraded pastures).

IFAD programmes in Kyrgyzstan **help poor livestock keepers** make their herds more productive by channelling support through pasture user unions. The Agricultural Projects Implementation Unit (APIU) and Community Development and Investment Agency (ARIS) are the main government agencies implementing the programmes. They work closely with pasture user unions, as well as with other government agencies, NGOs and other stakeholders.

From geo-tagging investment sites, updating old Soviet-era maps, establishing early warning systems – **IFAD programmes have applied GIS in a number of ways** to support herding communities better manage their pastures and cope with climate change.

Geo-tagging investment locations

IFAD's Livestock Market Development Programmes (LMDP I and LMDP II) systematically mapped over **2,000 investment locations** of pasture user unions. These included, for example, waterpoints, bridges, vetshops, housing for shepherds and bakery pits to dispose of dead animals. This helped programme management teams to keep track of investments. It also helped IFAD to get an impression of the geographic coverage and the types of investment. All offices were equipped with GPS. Field officers were trained on how to record location data. The GIS expert of ARIS coordinated all efforts, collected the data and placed it on a web-GIS. Geo-tagging was also part of procurement procedures: this means that every service, piece of infrastructure or machinery that went through procurement, a geo-location was collected

RESOURCES

Early warning system
Policy brief
Pasture condition maps

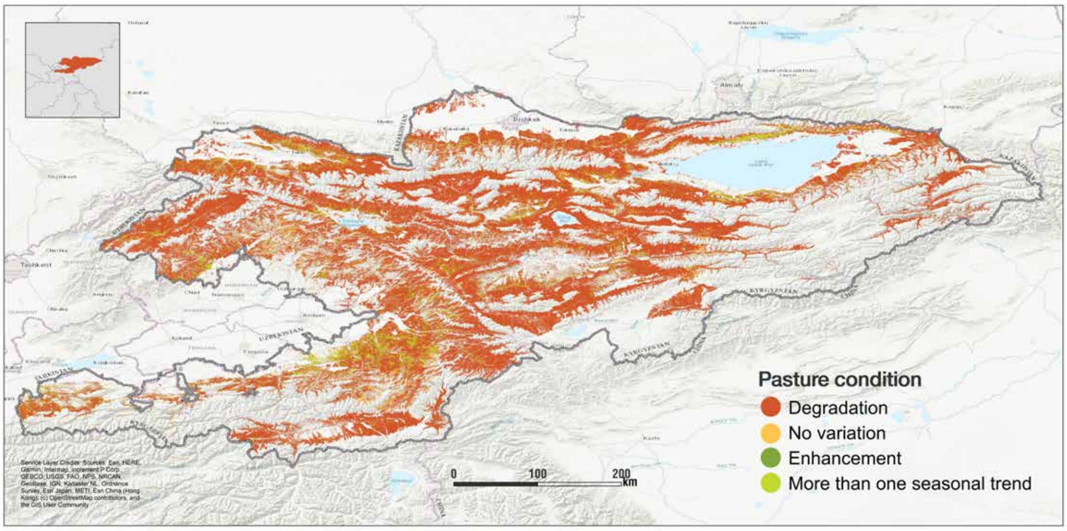

Figure 3: Combined pasture condition map of all four seasons comparing the periods 2000–2004 and 2014–2020 computed by the Climate Resilience Cluster of the EO4SD.

Early warning and pasture information system

Herders need to know in advance about potential weather extremes, so that they have enough time to move their animals (and themselves) to safety. LMDP II established a web-platform and app to provide herders with reliable weather forecasts and alerts. The forecasts and alerts are issued by Hydromet – the Kyrgyz meteorological office. The system issues warnings for **eleven weather hazards**: strong winds, heavy rainfall, dust wind, fog, slippery roads, wet snow, lightning, hail, temperature fluctuations and flooding. The platform also contains **information on pastures** such as their boundaries, infrastructure and the location of mountain passes. From April 2020 to April 2021, 351 alerts (of which 32% of high magnitude) were issued for 52 weather events that affected pastures across the country.

Mapping pastures

LMDP II provided **new pasture maps to 308 pasture user unions**. Pasture maps accompany pasture management plans and are essential tools to plan grazing activities. Maps also help communities identify gaps in infrastructure, allocate no-grazing areas, and plan for veterinary services. Previous maps were developed in the early 90s and were outdated. Teams of GIS experts and field staff worked together with community representatives to update and digitise these maps. The participatory mapping exercise took place over six months. Three types of maps have been developed for each pasture user union:

- **General map** depicting the contours and area of pastures, relevant infrastructure (e.g. shearing sheds, vetshops, water points and bridges), certain pasture characteristics (e.g. if stony or waterlogged), and other layers such as roads, rivers, settlements, cropland and other land uses.
- **Pasture boundary map** containing area names and information on seasonality of use, yield and capacity of pastures, as well as the area of pastures before and after mapping, as well as pasture infrastructure.
- **Maps at smaller scales** for ease of use showing the boundaries of pastures reflecting information on yield, capacity and number of grazing days.

GIS experts sat down with pasture users to capture their feedback and to validate and correct the information given. Recent satellite imagery was used to update the maps. A digital elevation model at 10m resolution was used to map steep areas unsuitable for grazing. The normalized difference vegetation index (NDVI) and pasture degradation maps were used to assess pasture conditions.

Assessing pasture conditions

Valuable insights on **pasture degradation** were obtained by a study undertaken by the Climate Resilience cluster of the Earth Observation for Sustainable Development (EO4SD) initiative, a programme funded by the European Space Agency (ESA). Analysts worked together with IFAD and Kyrgyz partners to compare the average pasture conditions of the periods of 2000–2004 and 2016–2020 using remote sensing imagery at 30m resolution. The analysts used the following data sets:

- Landsat imagery from NASA;
- Information on pasture types and grazing periods provided by NGO CAMP Alatoo;
- A land cover map and field measurement from FAO; and
- Digital elevation model from the Shuttle Radar Terrain Mission Digital Elevation Model.

The study revealed that 94% of pastures covering an area of over 69,900 km^2 are degraded at least during one season per year. Over 40% of summer pastures have been severely degraded since 2000–2004. Winter pastures are the worst affected, with 82% being severely degraded. The maps were used in the following ways:

- **Informing climate policy**: The maps informed the update of the country's Nationally Determined Contributions (NDCs) (Kyrgyzstan's commitments to reducing emissions and adapting to changing climate in line with the 2015 Paris Agreement).
- **Informing pasture maps**: The data was used in the pasture mapping process (as described above) to highlight areas that suffer from long-term degradation.
- **Assessing impacts**: The data fed into the impact assessment of LMDP II, revealing that pastures, especially winter ones, were in a better condition thanks to the programme. The share of healthy winter pastures has increased by 4% in the programme area.

LMDP II funded water points, like in the picture above, that help herders.

Assessing climate resilience

Uncovering the impact of rural investments on climate resilience

Do IFAD investments make the rural poor more climate-resilient? IFAD answers this question through rigorous "impact assessments" at the end of projects. IFAD surveys households to gather data on their agricultural production, incomes, livelihoods and well-being. These surveys also capture the geo-location of the sampled households, making it possible to superimpose agro-ecological characteristics and climatic variables such as rainfall, evapotranspiration and temperature for a specific location. The data on climatic variables feed into econometric models to find out the impacts the project has had on helping farmers adapt to climate change.

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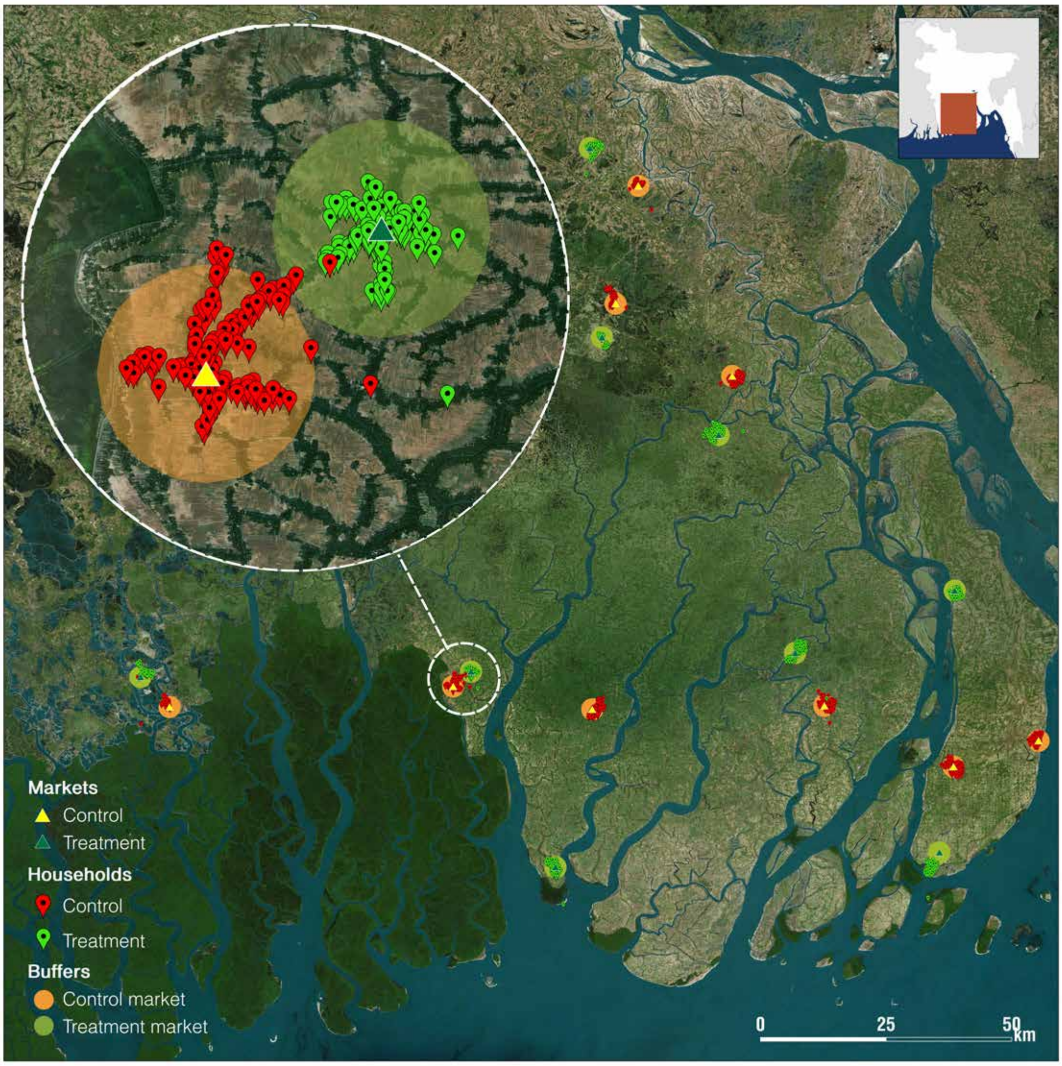

Figure 1. Market and household locations of the impact assessment of the Coastal Climate Resilient Infrastructure Project in Bangladesh.

Author: Oliver Mundy | Design: Tuuli Sauren | Maps: Rakhat Zhanuzakova | Editing: John Laird

Development projects aim to bring positive change to the lives of vulnerable people, but **measuring what impact a project has had can be very challenging**. This is even more the case when assessing climate resilience – the ability of households to cope with climatic shocks.

> **IFAD's impact assessments evaluate changes that can be attributed to the project investments.**

IFAD has established rigorous methods of data collection and statistical analysis, as well as careful quality-control procedures. Fifteen per cent of completed IFAD-funded projects undergo an impact assessment.

Comparing groups and areas

Impact assessments compare a representative sample of project beneficiaries (the **treatment group**) with a similar group of individuals not exposed to the project intervention (the **control group**). By comparing the two groups, it is possible to assess the changes that are attributable to a project. In most cases, the assessments compare households that have and have not received support by a project, but the unit of observation may also be small-scale businesses or producer organisations.

> **Selecting the right control group is essential.**

The control must resemble the treatment groups in as many aspects as possible at baseline. Geospatial data can help select suitable control groups and areas.

Collecting data

Data are typically collected from between 1,500 and 3,000 households using a **standardised questionnaire** with over 500 questions. Interviewers use tablets equipped with data collection software (in most cases Survey Solutions). The questionnaire gathers information about each household's socioeconomic characteristics, its livelihood and income-generating activities, its food security, social capital, and experience of climatic and socioeconomic shocks.

All the surveyed households are geo-referenced. This makes it possible to overlay the household information with data from other sources, including remote sensing and data on vegetative cover, soil quality, agricultural production, land and agroecological variables as well as presence of infrastructures and facilities. Because farming is highly dependent on the weather, the impact assessments also include geo-referenced climatic variables and historical values on such things as rainfall and temperature as well as the coefficient of variations and anomalies occurred during the agricultural season connected to the data collected at household level.

Analysing impacts and checking for quality

The household survey data and the GIS-derived information is then fed into an **econometric model that compares the treatment and control groups** and accounts for the influence of various independent variables, such as rainfall, soil type, market access and population density. Robustness checks are carried out to ensure confidence in the results.

The econometric model can determine whether climate and weather variables either foster or inhibit the attainment of the project outcomes. For example, they may reveal whether unusual rainfall in a particular year has affected farmers' yields and income from a particular crop promoted by the project.

RESOURCES

IFAD impact assessments

Climate Action Report 2019

Story map Mexico

Impact assessments

Bangladesh

Mexico

Rwanda

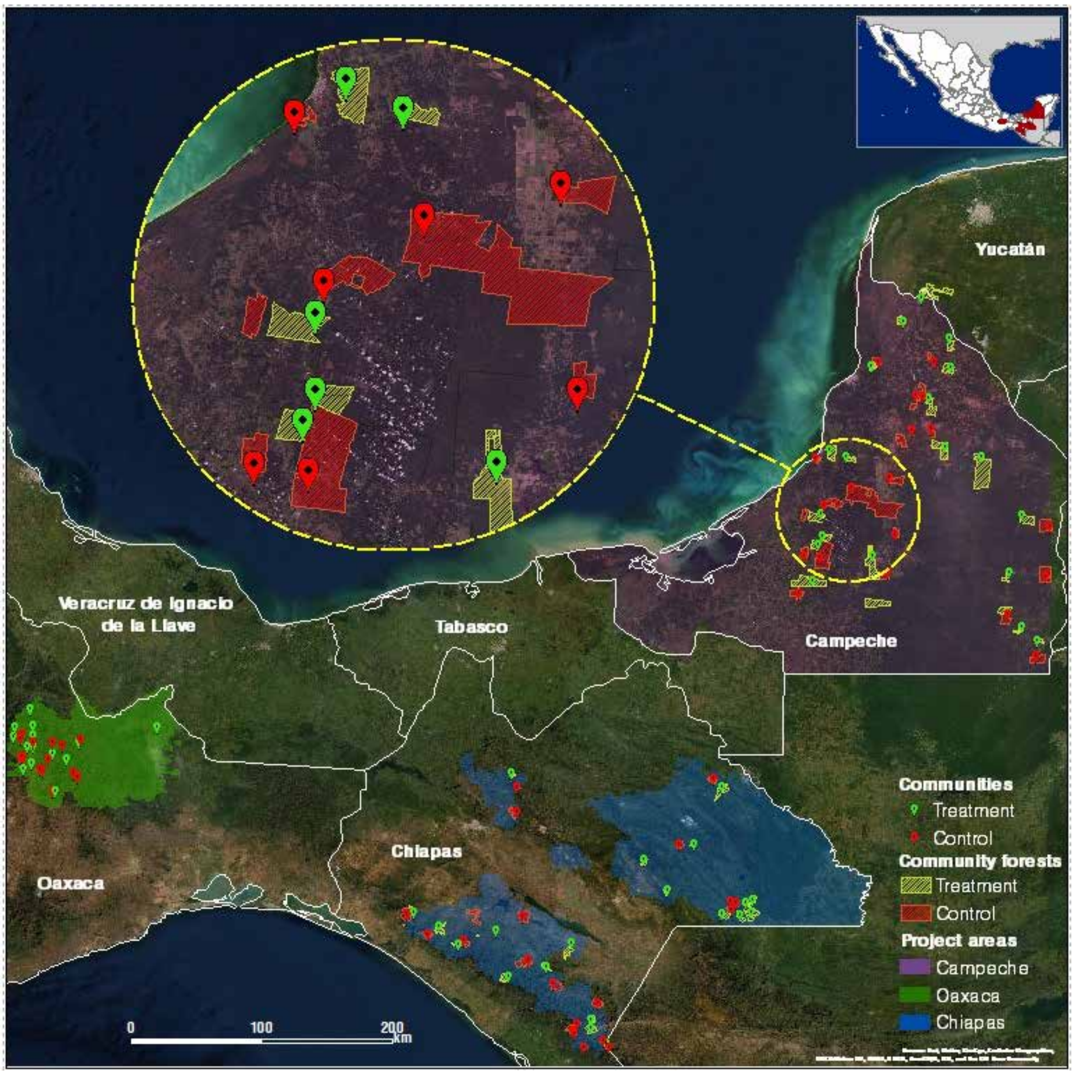

Figure 2. Locations of communities and their forests used in the impact assessment of the Community-based Forestry Development Project in Southern States in Mexico.

Bangladesh: Climate-resilient infrastructure boosts income

The impact assessment of the Coastal Climate Resilient Infrastructure Project revealed that **beneficiaries' incomes increased because of the better market access** created by the project. Market access was poor, especially during the monsoon season, when markets and roads become flooded and unusable. The project improved markets by installing raised areas and drainage systems to prevent flooding. It provided facilities such as toilets and river docks, and trained market stakeholders. It also constructed roads raised above the flood level that are bordered with vetiver grass to stabilize road sides.

The evaluators had the GPS coordinates of market locations that the project developed as well as of markets where no intervention had taken place. Using GIS, the evaluators calculated areas surrounding each market to approximate its catchment area, and calculated the distance of each household to the nearest market. The study revealed that the incomes of beneficiaries within the market catchment areas had increased. Their income from crop sales was 130% higher than the control group in the dry season and 70% higher in the monsoon season.

Mexico: Healthier forests increase resilience to droughts

The Community-based Forestry Development Project in Southern States introduced a range of initiatives to address deforestation in southern Mexico by training local communities to manage forest resources more sustainably, and by helping them to generate income from agroforestry products as well as from additional business activities such as ecotourism. The impact assessment collected data from 2,200 households. In

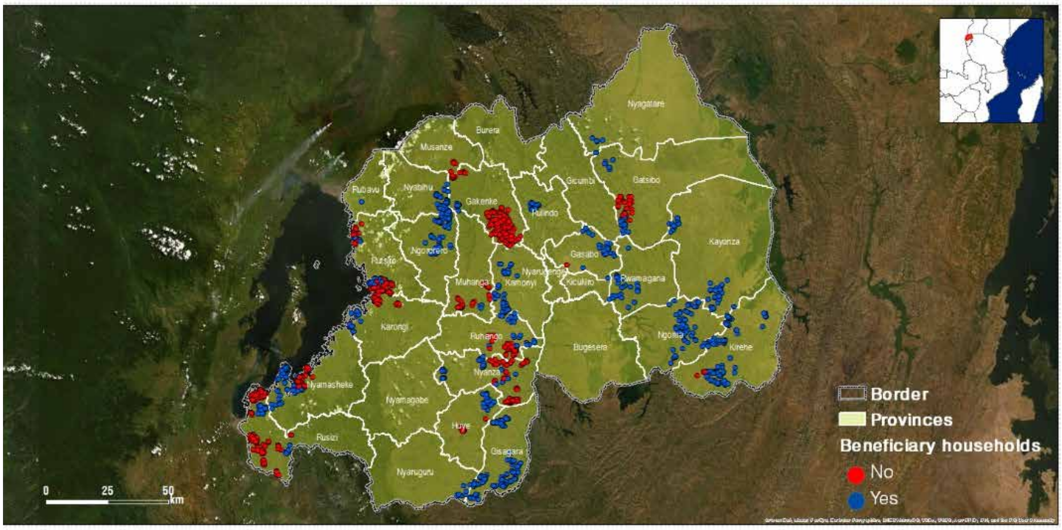

Figure 3. Households surveyed for the impact assessment of the Project for Rural Income through Exports in Rwanda. Points are clustered together because of households belonging to a cooperative.

the state of Campeche, where communities own large forested areas, project activities focused on **strengthening the sustainable use of forest resources**. This has led to **stronger resilience to droughts** and other climate shocks.

Rwanda: Extreme rainfall affects coffee production

The Project for Rural Income through Exports supported coffee producers in Rwanda from 2011 to 2020. Over 2,800 households associated with coffee cooperatives were surveyed as part of the impact assessment. Around half of them benefited from the project. The study revealed that **heavy rainfall cut the coffee production** of all farmers (35% lower yield), but farmers who benefited from the project were affected less (by 8%).

Drought was often assumed to be the main climate problem facing coffee farmers, but this study showed that heavy rain, even without flooding, can cause great damage. Future adaptation interventions need to address excessive rainfall to improve coffee yields in Rwanda.

GIS study in Sierra Leone

Fighting fires with rice paddies

Farmers in Sierra Leone have shifted from slash-and-burn cultivation to rice cultivation in inland swamps. That is reducing the number of forest fires, a GIS study has shown.

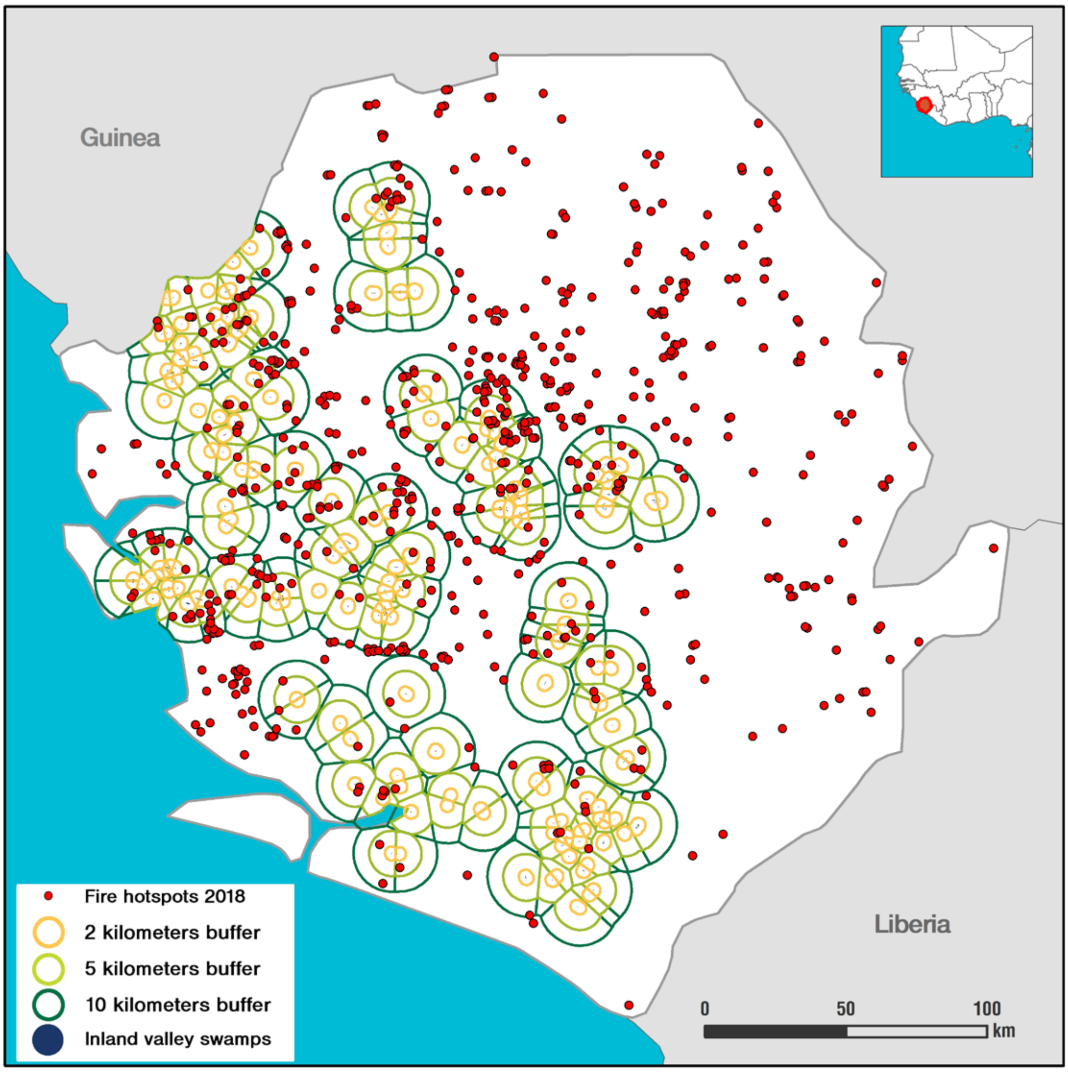

Figure 1. Locations and buffers (of 2, 5 and 10 km) around developed and undeveloped inland valley swamps, as well as fires recorded in NASA's Fire Information for Resource Management System (FIRMS) in 2018.

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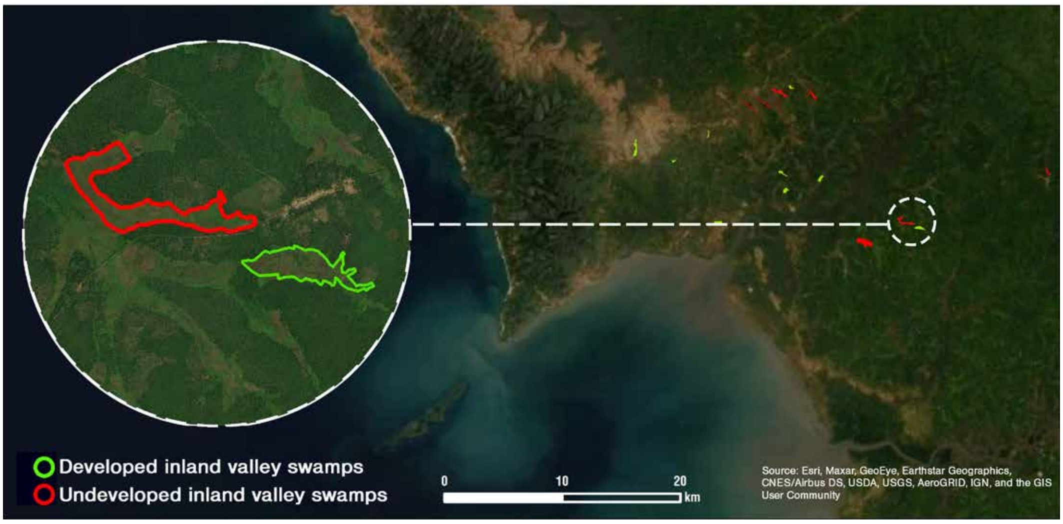

Figure 2. Developed and undeveloped inland valley swamps.

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Low-cost irrigation systems developed by the project increase yields of rice paddies in inland valley swamps.

The IFAD-supported **Smallholder Commercialization Programme**, that finished in 2019, helped farmer groups develop low-cost irrigation systems in swamps in the valleys which allowed them to **grow irrigated rice three times per year as opposed to just once**. These higher yields brought about gains in income and food security for the farmers; and the new irrigation systems helped prevent rice seedlings from being washed away during heavy downpours.

Yet a GIS study of the programme area showed an additional **unexpected benefit** of improving wetland rice cultivation in valleys: **it reduced forest fires**.

Farmers in forested areas of Sierra Leone normally clear a patch of land in the forest so they can grow rice and other crops. They often do this by **burning the land**. They cultivate the land for several years until the soil fertility declines, then move to another area, which produces low yields and harms the environment.

But the GIS study has shown that the development of rice paddy fields in the programme area is reducing the number of forest fires in the surrounding areas. Farmers have shifted from slash-and-burn cultivation in higher areas to rice cultivation in inland swamps.

RESOURCES

Expert blog

Technical note

Webinar

Thanks to the thorough collection of GPS coordinates on the location of rice paddies by programme staff, IFAD's GIS monitoring and evaluation (GeoM&E) team were able to **compare swamps developed by the programme with other swamps that remained undeveloped**. They overlaid this information onto a dataset from NASA's Fire Information for Resource Management System (FIRMS).

> **There were on average 2.8 fewer fires a year within 10 km of the rice paddies developed by the programme, equal to a reduction of over 60 per cent during the duration of the programme.**

GIS and econometric analysis showed that there were an average of 1.0 fewer fires within a 5 km radius and 0.3 fewer fires within 2 km. These measurements remained the same after controlling for other possible confounding factors, including precipitation, temperature, degree of slope incline, and road infrastructure.

This analysis was only possible because the local programme staff **rigorously collected GPS coordinates on the swamps** as part of their efforts to plan, track progress, and report on outcomes. They mapped over 3,281 hectares of swamp, of which 1,411 hectares were ultimately developed.

The programme team had not anticipated that developing the swamps would lead to fewer fires. These results indicate that valley development of the kind undertaken in this programme has positive effects for both farmers and the environment. They also suggest that the valley development model could be replicated elsewhere in Sierra Leone. Efforts are already under way thanks to a new IFAD-supported project in the country.

© IFAD Oliver Mundy

Water flow that is not controlled damages rice seedlings and reduces yields.

© IFAD Smallholder Commercialization Programme

A programme staff member collects the GPS coordinates of a paddy.

ANNEX. Event recordings

IFAD organized a ShareFair – a virtual ideas marketplace – on 9 November 2021 as part of the COP26 climate summit in Glasgow. The event featured the presentation of 20 geospatial tools and applications for climate investments broken down into 10 "breakout rooms" (i.e. two presentations per breakout room). The recordings of the ten breakout rooms can be found below. Each presentation is 5 minutes. The session was moderated by Gladys H. Morales and Oliver Mundy from IFAD.

Opening remarks

- **Dominik Ziller**, Vice-President, IFAD
- **Jyotsna Puri**, Associate Vice-President, Strategy and Knowledge Department, IFAD
- **Ruandha Agung Sugardiman**, Director General of Forestry Planning and Environment Management, Ministry of Environment and Forestry, Indonesia
- **Maximo Torero Cullen**, Chief Economist, Food and Agriculture Organisation of the United Nations (FAO)
- **Benjamin Koetz**, Head of Sustainable Initiatives Office, European Space Agency (ESA)

Tools and approaches

Room 1

GeoTech4Tenure: Course for participatory GIS land recordation and mapping.
Harold Liversage, IFAD

Global Agro-Ecological Zoning platform: The future of crop production.
Gianluca Franceschini, FAO

Room 2

Earth Map: Tool for complex land monitoring.
Alfonso Sánchez Paus Díaz, FAO

Resilience design and monitoring tool.
Francesco Ajena, IFAD

Room 3

GeoM&E: Systematic integration of GIS in monitoring and evaluation.
Athur Mabiso, IFAD

Hand-in-Hand Geospatial Platform.
Karl Morteo, FAO

Room 4

Trends. Earth: Tool for tracking land change.
Tom Kiptenai, Conservation International

GeoScan: Spatial data country profiles.
David Hughes & Lyubomir Filipov, IFAD

Room 5

GeoAdapt: Climate vulnerability assessment tool.
Michelle Latham, IFAD & WFP

SEPAL: System for earth observation and analysis for land monitoring.
Yelena Finegold, FAO

Watch the full event here:

Case studies

Room 6

Nepal: GIS-supported, community-based adaptation planning.
Binod Prasad Devkota, ASHA Project

Central Asia: Building pastoral communities' climate resilience.
Carlos Domenech, GMV

Room 7

Targeting people vulnerable to climate change in Latin America.
Jose Caceres Martinez, IFAD

Supporting resilient food systems in sub-Saharan Africa.
Everline Ndenga, Conservation International

Room 8

Addressing climate concerns in project design.
Renaud Colmant, IFAD

Kyrgyzstan: Community mapping of pastures.
Erik Zheentaev, ARIS
Nagima Alimbekova, APIU

Room 9

Yemen project design: Overcoming COVID-19 and conflict constraints using GIS.
Giancarlo Pini, WFP

Rwanda: Uncovering the impact of climate and weather variables on coffee.
Athur Mabiso, IFAD

Room 10

Sierra Leone: Fighting fires with rice paddies.
Asti Asoka, IFAD

Lesotho rangeland health dashboard.
Tor-Gunnar Vågen, World Agroforestry Centre

@IFAD/Juan Ignacio Cortés

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