GEOGLAM
GLOBAL AGRICULTURAL MONITORING

Guidance Document On Good Practices For Designing, Implementing, And Evaluating Capacity Development Interventions In GEOGLAM

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Note on contributors

This Guidance Document was written by GEOGLAM for GEOGLAM with input from members of the GEOGLAM Capacity Development (CapDev) Team, key stakeholders, and interested parties. It was created to provide the GEOGLAM community with a common understanding of CapDev principles and processes.

We believe that an impact-oriented CapDev approach drives the core principle of GEOGLAM's CapDev: we strive to prioritize demand-driven interventions that focus on the users' needs.

This guide will be a living document. We encourage you, the reader, to contribute to the following content by sharing observations and/or comments for improvement with GEOGLAM's CapDev Team. Sharing new insights, proven tools, good practices, and case studies is highly appreciated.

Finally, we hope this document serves the GEOGLAM community in their endeavour to conduct and scale-up agricultural monitoring activities and associated CapDev interventions.

Executive summary

This document details good practices for designing, implementing, and evaluating CapDev relationships, based on a co-development process. It also includes case study narratives from GEOGLAM's members and stakeholders that exemplify successful engagement.

This Guidance Document consists of 6 sections:

- **Section A:** Describes the scope and target audience of the document.
- **Section B:** Describes CapDev from GEOGLAM's perspective and our Guiding Principles.
- **Section C:** Explains useful models and frameworks for approaching CapDev. e.g., the Theory of Change for defining how and why a change/impact will occur, and the Strategic Pathway as a framework for understanding the necessary steps to achieve the desired change/impact.
- **Section D:** Presents several tools that can foster impactful CapDev interventions and describes how to develop and deploy a continuous Monitoring, Evaluation, and Learning framework.
- **Section E:** Presents a series of GEOGLAM Case Studies, highlighting successful examples of GEOGLAM CapDev interventions.
- **Section F:** Summarises next steps future priorities for the GEOGLAM CapDev Team to ensure GEOGLAM continues to effectively support stakeholder needs for Capacity Development.

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A: Introduction

Capacity development (CapDev) is a key activity in GEOGLAM, focussing on user needs and impact

There is a growing demand for CapDev to use Earth observation for crop monitoring

This document is a hands-on resource for practitioners developing CapDev interventions

We aim to increase efficiency and impact by sharing CapDev tools/experiences in GEOGLAM

1. Why do we need this document?

GEOGLAM[1] is a community of practice. It is a bottom-up, best-efforts activity guided by the idea that inter- and intra-national collaboration and sharing of experiences, methods, data, and expertise can lead to a whole greater than the sum of its parts.

This Guidance Document provides a historical look at GEOGLAM activities that have been particularly successful with respect to CapDev, and a current narrative of GEOGLAM's approaches. It is also a forward-looking vision for how our community can grow and evolve, learn from our experiences, and leverage that knowledge to better adapt to highly dynamic agricultural and policy landscapes.

Our key objective is to make the Guidance Document a useful, hands-on resource for individuals and projects/programmes that have ambitions to conduct and scale-up agricultural monitoring activities and associated CapDev interventions. We aim to follow our own recommendations for stewardship by maintaining the Guidance Document as a living document on GEOGLAM's website.

A Guidance Document was also requested by our community of practice and the agencies from which we draw research and operations funding. These groups rightly observed that GEOGLAM needs a unified voice around CapDev principles, while still allowing flexibility of implementation. As such, this document—written by members of the GEOGLAM CapDev Team, the CEOS WGCapD co-chair, GEO Secretariat's Impact Design Officer, and key stakeholders/interested parties—presents good practices for designing, implementing, and evaluating CapDev relationships, based on a co-development process. It also includes narratives of case studies from GEOGLAM members and stakeholders on examples of successful engagement.

CapDev has always been a key activity for GEOGLAM partners—this has been the case since before the initiative's formal inception. In fact, many of the early GEOGLAM participants were connected through technology transfer and CapDev engagements. Through our work, we found that the greatest impact on human well-being occurs when nations are enabled to autonomously gather their own information within mandated agencies close to the programmes and policy actors that can make use of it. Autonomy yields trusted information that can quickly be turned into decisions. This drives the core principle of GEOGLAM's CapDev approach: we strive to prioritize demand-driven interventions that focus on the users' needs.

CapDev interventions are spread across several GEOGLAM activities—for example, many of the projects that make up GEOGLAM have their own capacity development component—which has led to considerable agility, flexibility, and impact. However, a sub-ideal outcome of this decentralised approach has been a lack of continuity across time or connection across projects, leaving valuable

Figure 1 - CapDev on individual, organisational and institutional levels (Source: Towards a GEO Strategy for Capacity Development)

opportunities for synergy uncaptured. At the same time, demand for technology transfer and CapDev across GEOGLAM partners continues to grow, meaning that increasing efficiency while amplifying impact is essential.

To effectively respond to this need, it is necessary to better coordinate and harmonise activities across the contributing initiatives, to support the maintenance of transferable resources, and to connect with related parallel efforts such as the CEOS WGCapD[2], the GEO CD-WG[3] and GEO Knowledge Hub, LearnEO, the RoadMap for EO education, EOTECDevNet[4], and GODAN[5].

GEOGLAM established a capacity development working group in 2019 (CapDev Team) to address the need for harmonisation, building upon the prior decentralised efforts that date back to GEOGLAM's 2011 inception. The role of the CapDev Team is to promote a community of research and an operationalisation agenda, develop a strategic vision for CapDev for GEOGLAM, document and promote good practices around CapDev, and support the research-to-operations cycle with the scientific leads and teams. The overarching goal of the CapDev Team is to develop individual, organisational, and institutional capacity and capabilities to use GEOGLAM outputs. The three levels are visualised in Figure 1.

Box 1: How can the Guidance Document support the GEOGLAM community?

The Guidance Document has been reviewed and accepted by the GEOGLAM ExCom, and socialised with CEOS and GEO. Pending outcomes of those engagements, endorsement may be sought by GEO. Through these engagements, the document could then be included in future funding calls that support GEOGLAM's CapDev efforts. Proposals to those calls would then make best use of the knowledge in the community, **increasing the likelihood that funded projects which contribute to GEOGLAM will meet their objectives with respect to CapDev itself**. GEOGLAM requires the support of the community for its coordination efforts. Inclusion of the Guidance Document in funding calls is one mechanism to improve the incorporation of funded project outcomes into GEOGLAM CapDev efforts.

2. Who is the target audience?

The Guidance Document is written by GEOGLAM for GEOGLAM, as well as for those organisations that aim to support GEOGLAM through funding, provision of satellite data, and in-kind contributions. It is for anyone who could utilize a collection of GEOGLAM community knowledge and practice to further support the GEOGLAM community in their CapDev interventions. This follows in the GEOGLAM tradition of drawing together community experiences to create a synergistic whole that amplifies the sum of its constituent projects and programmes.

By further targeting organisations that GEOGLAM interacts with, including government agencies, CEOS, and the policy bodies and frameworks which comprise GEOGLAM and GEO's priorities (e.g., G20[6], UN SDGs[7], Sendai[8], and UNFCCC[9]), we can strategically leverage multiple financial resources while meeting the core UN SDG high-level goal of reusing data and resources for multiple purposes. Finally, it can also be used as a resource for the whole GEO community—not all GEO activities may have the resources or time to develop CapDev documents and tools.

3. This document at a glance: collaborative and iterative design, implementation, and evaluation of capacity development interventions

Section B: We begin by describing CapDev from GEOGLAM's perspective and identifying our Guiding Principles. GEOGLAM proposes to apply an impact-driven approach, a collaborative process of problem-solving, and achieving measurable impact by strengthening the capacities and capabilities of the parties involved. To maximise impact, CapDev for GEOGLAM needs to be active throughout a project's lifetime, with pre-project relationships in place and a plan for post-project stewardship. Following a co-creation approach, i.e., working hand-to-hand with users from the start, is one of the best ways to ensure that developed approaches are fit-for-purpose and more likely to be sustained beyond projects' lifetimes.

Section C: We then describe models and frameworks for approaching CapDev. We explain the Theory of Change model, the Strategic Pathway framework for understanding the necessary steps to achieve the desired change/impact, the assumptions between the different steps and, finally, its visualisation.

Section D: We then follow with practice and tools for impactful CapDev interventions and discuss how (and why) to develop and deploy a continuous Monitoring, Evaluation, and Learning framework. You may be familiar with some tools already, so we do not expect you to read every page in this section. However, we recommend that you read section C first and then choose what you want to learn from section D.

Section E: We present a series of GEOGLAM Case Studies which highlight successful examples of GEOGLAM CapDev interventions.

Section F: We briefly look back at lessons learned and set out future priorities for the GEOGLAM CapDev Team to ensure that GEOGLAM continies to meet the increasing demand for CapDev for agricultural monitoring.

B: CapDev in GEOGLAM

GEOGLAM's **definition and aims** of CapDev development align with GEO and UNDP

GEOGLAM's CapDev principles represent **current practices** and **future aspirations**

The changes that occur due to GEOGLAM CapDev interventions empower and benefit **individuals, organisations, and institutions**

1. The GEOGLAM approach to capacity development

Existing definitions aside, the CapDev Team wrote a GEOGLAM-specific definition of CapDev that clearly communicates GEOGLAM's role in CapDev externally and guides our activities internally. Our definition builds upon existing concepts and definitions within GEO[10], GEOGLAM[11], and the UNDP CapDev Primer[12], and has been adapted from those to fit with GEOGLAM's activities for CapDev.

GEOGLAM defines CapDev as a co-creation process *through which individuals, organisations, and institutions collaborate to obtain, strengthen, and maintain their capabilities to use Earth observations for sustainable agricultural development and for responding to challenges associated with maintaining and increasing agricultural production and food security. Co-creation covers both the design and implementation.*

Co-creation **is about equal partnership, shared ownership, joint responsibility, and stakeholder engagement.** It recognises the needs, ambitions, knowledge, and specific expertise of the participating parties, positioning **the requester** at the centre of any planned engagement. It is a collaborative process of problem-solving within a learning cycle, rather than just providing the solutions. It aims to merge and strengthen the capacities and capabilities of all parties involved (individuals, organisations, and society as a whole) to create value. Critically, co-creation is an explicit rejection of development paradigms which centre on the "donor", that have a track record of leaving recipients with little enduring change. This roundtable vision of collaboration and discussion between parties fosters the identification of gaps and barriers while also opening space for ideas to support EO uptake to emerge. This process is about addressing the desired change by jointly achieving outputs, outcomes, and even societal impact, in addition to ensuring the quality and quantity of inputs and outputs.

CapDev interventions in GEOGLAM aim*, through this co-creation process, to increase the technical and human capacity of individuals, organisations, and institutions to:*

- *fully utilise EO data and information in agriculture-related decision-making processes.*
- *enrich organisational workflows through the use of EO-based analytics for monitoring agriculture.*
- *distribute good practices that showcase the value of EO and promote the engagement of institutional users.*
- *strengthen the political, social, and technical framework in which individuals and organisations operate.*

Following the definitions of UNDP[13] and OECD/DAC[14], CapDev is about transformations that empower individuals, leaders, organisations, and societies. It is the ability of people, organisations, and society to manage their affairs and resources successfully, sustainably, and efficiently. These definitions imply a holistic approach to CapDev which encompasses the three levels of interventions: on an individual level by increasing individual awareness of and capacity to access, use, and develop EO data and products; on an organisational level by increasing organisational awareness of, and capacity to access, use, and develop, EO data and products to subsequently adapt into their workflows; and on an institutional / societal / systemic level by increasing societal awareness of the relevance of using geospatial information for planning, decision-making processes, and achieving societal impact.

CapDev outcomes for GEOGLAM *are achieved when CapDev activities lead to a beneficial transformation that is generated and sustained over time from within the requester organisation. These transformations include the integration and/or improvement of EO in workflows where they become internalised as part of routine operations as well as changes in attitudes and mindsets about the essential value of EO for agricultural monitoring. The bottom line is that these transformations empower and benefit individuals, organisations, and institutions.*

2. The GEOGLAM guiding principles for capacity development

GEOGLAM is built upon common interests and good intent. As such, these principles are aspirational and intended to help guide how different CapDev interventions are handled within GEOGLAM. Figure 2 presents GEOGLAM's principles. For some of these factors, we are currently delivering concrete results across all projects in GEOGLAM's bottom-up portfolio. However, some principles have not been explicitly stated in a GEOGLAM document before. Thus, this document aims to set forth a forward-looking vision and not merely rehash the status quo.

Start with existing capacities

CapDev interventions start with the capacities and capabilities that already exist within the engaged parties. Human capacities (skills and knowledge) and the capabilities of requester organisations, individuals, and institutions will be strengthened by bridging the gap between the existing and required competencies for the uptake of EO by staff, and by identifying the organisational needs to facilitate the strengthening of the required competencies.

Interventions should be demand-driven and impact-oriented

Starting with a need or demand for information is a critical component of co-creation that ensures projects begin with a clearly defined impact. Different frameworks can be used to understand the required interventions needed to reach a desired impact (e.g., Baseline Studies, Logical Frameworks, Result Chains, Strategic Pathways, etc.) In GEOGLAM, CapDev interventions often focus on strengthening national agricultural monitoring systems. In a broader context, GEOGLAM's impact also highlights the international relevance of multiple national-level activities. Co-creating national competencies in EO-based crop monitoring relates to several international development targets as set out by the UN SDGs, the Paris Agreement on Climate Change (under the UNFCCC), the Sendai Framework for Disaster Risk Reduction, and/or Aichi Targets of The Convention on Biodiversity, among others.

Use a co-creation approach

Many CapDev interventions focus on individual capacity strengthening via training, massive open online courses (MOOCs), webinars, etc., which share or transfer new knowledge, skills, and insights in only one direction. The GEOGLAM perspective is that these are effective tools for information sharing that must be situated within a more holistic co-creation approach to CapDev, one in which partners jointly share in the design and implementation of a CapDev intervention.

Fit-for-purpose approach

A "fit-for-purpose" or "good-fit" approach requires a clear understanding of different audiences' specific needs and builds upon existing capabilities. Any assumptions that are made in the approach need to be validated. The "uniqueness" of participating public and private institutions does not allow a "one-size-fits-all" development process for designing CapDev interventions. The capacity of an individual or organisation to take up data products for decision-making will vary. Hence, each of the identified audiences—whether a service developer, service receiver, political authority, end-user, or influencer—will become part of the targeted CapDev interventions and will be addressed according to their role, needs, capacity, interest, and influence.

Stakeholder engagement

Multiple stakeholders relevant to GEOGLAM should be identified and engaged based on their specific role, interest, and influence. The spectrum of stakeholders ranges from hands-on users of EO-related technology up to the highest political level, with a broad range of actors in between. Hence, a range of engagement activities, including technical, political, and even personal, is essential.

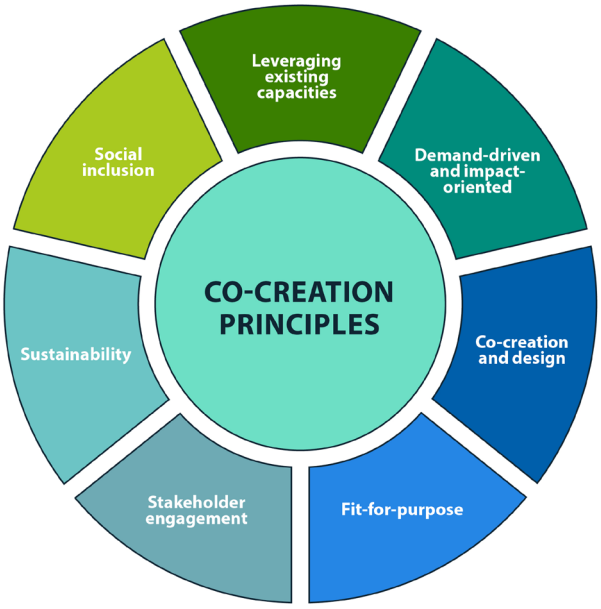


Figure 2 - GEOGLAM's principles for CapDev (Adapted from the Digital Earth Africa capacity development strategy)

Plan for continuity

Continuity here refers to the sustained provision of dependent data and services implicated in the CapDev intervention, as well as of sustained use of the EO data and tools within the requester organisation regardless of staff turnover. Ensuring organisational, technical, financial, data, and academic continuity will be addressed during the project period and, if warranted, operationally sustained post project. This can be done through:

- the buy-in at policy level, here meaning the establishment of high-level requester organisation commitments to transborder and multi-organisational policy and community frameworks (e.g., GEOGLAM, UN SDGs) that remain regardless of turnover within organisations.
- the development of institutional and technical frameworks that fit within the organisational structures of the requester, enhancing the likelihood of post-project relevance and continuity.
- the development of sustainable business and financial plans within the requester organisation, or with that organisation's network, for maintaining skills, data, services, or tools.
- the establishment of strong networks for information and knowledge sharing.
- a plan for updating relevant technical infrastructures beyond the initial project period.
- the non-cessation of all contact at project close. That is, Principal Investigators and key team personnel maintain relationships beyond a project's lifetime.

This principle represents a paradigm shift within short-term funding structures, away from finite periods of engagement and toward relationship and outcome-oriented engagement.

Be realistic about what can be accomplished with available funds

CapDev is a factor in addressing broader systemic challenges, which might quickly become associated with costs exceeding the budgets of typical GEOGLAM projects. The CapDev budget should factor in costs for the collaborative Strategic Pathway design process as well as the Strategic Pathway's implementation—this may result in significant work requiring a substantial number of face-to-face meetings, calls, and workshops to realise the desired impact or change.

In practice, the CapDev budget might be limited. It is important to clearly define both the scope and the budget to avoid offering unrealistic outcomes and unattainable expectations. If the budget is limited, you will need to prioritise your activities (consistently in line with your "priority outcomes") or find alternatives. Because the process of setting priorities is inherently political, specific efforts should be made to manage it carefully and transparently, with the involvement of all relevant stakeholders.

Share the lessons learned: utilisation, diffusion, and communication

A major objective in GEOGLAM is building synergies across projects and activities under the broad GEOGLAM umbrella. For that reason, it is important that GEOGLAM partners synthesise "What Happened" and "Lessons Learned" in developing and carrying out a CapDev intervention. As such, we encourage partners to develop a strategy for sharing lessons learned and outcomes. Figure 3 presents examples of activities and outputs that can showcase the outputs of a CapDev intervention.

Figure 3 - Examples for showcasing what happened and what worked in a CapDev project (source: J. Teuben - ITC workshop on Impact)

Diversity, equity, equality, and inclusion

GEOGLAM is an international organisation. As such, it adopts the language and principles set forth by the United Nations General Assembly in its 2012 "Declaration of the High-level Meeting of the General Assembly on the Rule of Law at the National and International Levels." This A/67/L.1 text reads:

"We… support all efforts to uphold the sovereign equality of all States… and respect for the equal rights of all without distinction as to race, sex, language, or religion, international cooperation in solving international problems of an economic, social, cultural or humanitarian character, and the fulfilment in good faith of the obligations assumed in accordance with the Charter." [para. 3]

We further amend this text to explicitly condemn discrimination on the basis of race, colour, ethnicity, national origin, religion, sex, gender identity or expression, sexuality, disability, age, marital status, family/parental status, or political beliefs. Simply, GEOGLAM as an organisation treats all partners as equals and selects partners without privilege or bias and expects all partners to do the same when working in this international context.

C: Models and frameworks for successful Capdev: theory of change and strategic pathways

The **Theory of Change** (ToC) helps describe the problem to be addressed and the desired changes

ToC focuses attention on the end goal—**impact**—rather than on **activities**

ToC makes your **assumptions** explicit and challenges you to **validate** them before starting

By developing **indicators**, a ToC is also a reference for **monitoring** and **evaluating** interventions

The **Strategic Pathway** describes the series of steps and milestones for reaching the desired change or impact laid out in the ToC

1. Theory of change model

The Theory of Change (ToC) model is a description of how and why a desired change or impact is expected to happen in a particular context. The process of creating a ToC surfaces the "theories" you consciously or unconsciously hold resulting from personal perceptions of reality and beliefs (assumptions) and helps you define the need you are trying to address (problem and impact). From there, you can identify the changes you want to make (outcomes), what you want to achieve (outputs), what you plan to do (activities), the kind of resources needed (inputs), and how to track progress and adjust course (monitoring, evaluation, and learning, or MEL). Once defined, these factors can be combined to create Strategic Pathways.

The ToC approach offers several benefits, as described in box 2.

Box 2: The benefits of the theory of change approach

Strategy

- To help teams work together to achieve a shared understanding of a project and its aims.
- To make projects more effective.
- To identify and open up 'black boxes' in thinking.

Measurement

- To determine what needs to be measured and plan evaluation activities.
- To encourage teams to engage with the existing evidence base.
- To act as the basis for claims about attribution.

Communication

- To quickly communicate project aims to different target groups.
- The steps which lead to bringing the process of change to the forefront; steps which lead towards the final goal.

Partnerships

- To support partnership engagement.
- To define clear roles and responsibilities.

Visualisation

- To visualise the project outline and strategic pathways in one schematic overview.

2. Designing the ToC for CapDev interventions

By developing a ToC, you can link what a CapDev intervention does with how that intervention leads to achieving desired goals. Crucial to the ToC model is the definition of the problem area to be addressed, and the assumptions underlying the perceived process of change.

The critical thinking implicated in this approach provides insight into the assumed causal logic of outputs, outcomes, and impact; how different Strategic Pathways might lead to the desired change and why the Strategic Pathway ultimately selected is "the best."

By applying the ToC model, several steps can be identified in the CapDev development process.

Figure 4 presents the cyclical and iterative impact planning process. The blue boxes represent the different steps. The green boxes present tools to be used in the identified steps.

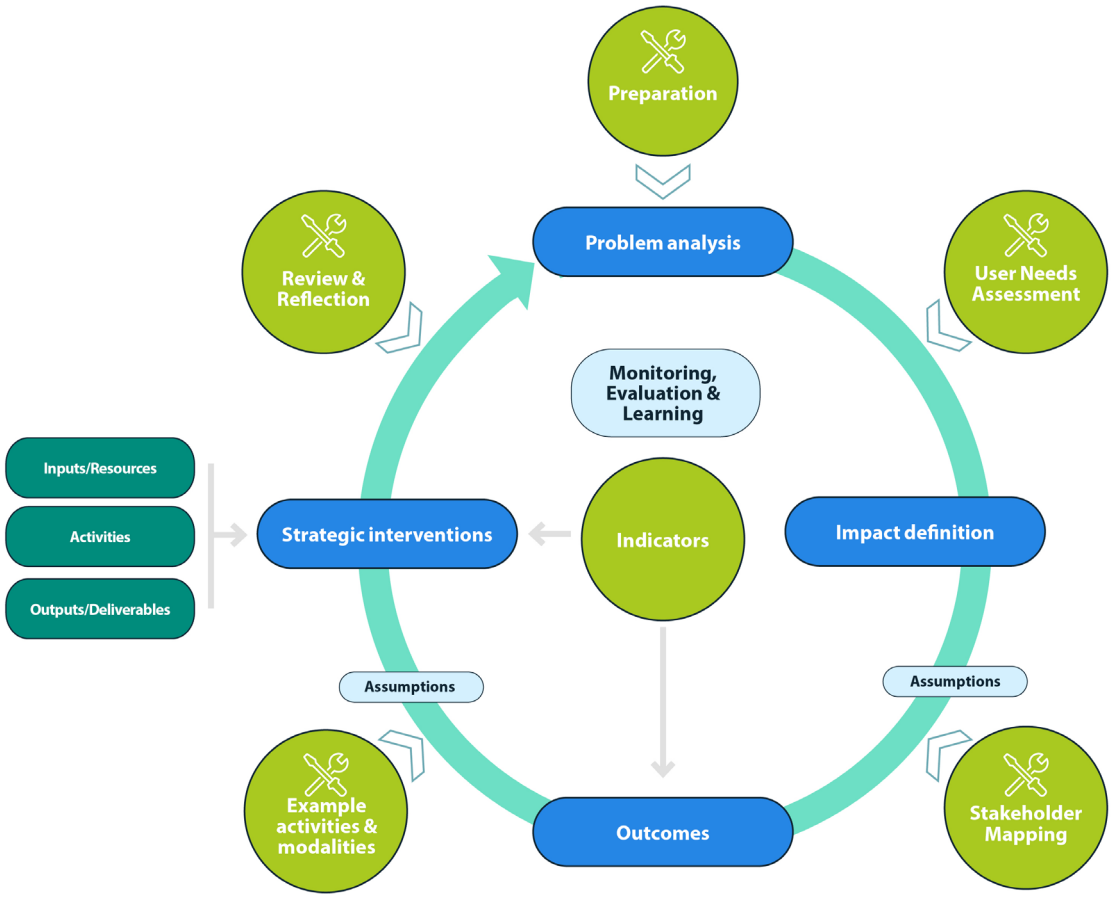


Figure 4 - The ToC design process (Source: J. Teuben)

Step 1: Analysing the problem

Before defining the desired impact, partners must work together to describe the problem or challenge that will be addressed by the CapDev intervention (see Tool 1: Preparation in Section D).

Answering the following four questions will help to define the problem area/statement and understand whether/how/which capacity development for information/knowledge development can help:

1. What is the problem that needs to be solved?
2. What are the causes of the problem?
3. Could any of these causes be mitigated by increasing knowledge or information, and/or equal access to this knowledge or information? If so, which?
4. What are the gaps in knowledge or information, and/or the capacity to generate this knowledge, particularly within the requester organisation?

Step 2: Defining the desired impact or change

Once the problem has been clearly defined, partners must agree on what long-term impact(s) will be achieved through the intervention. This is best accomplished through a consultation process during a dedicated meeting of partners, while considering the result of the User Needs Assessment (Tool 2: Section D) and the problem statement.

The consultation process should answer the following questions to define the impact:

1. What is the expected (societal/organisational) change or impact in response to the problem statement?
2. Who are the key actors and factors that determine the context (what is their interest, what is their motivation, what is their role, what are their relationships, etc.)?
3. Which actors and which resources are crucial for success?

Impact(s) must be both ambitious and achievable. Your impact(s) must be convincing enough to motivate stakeholders to learn and adopt new practices and to induce the desired change(s).

By nature, and as previously stated, impacts are often longer-term goals, and may not be realised until after a project has concluded. If the impact is very long-term or very ambitious, it can be useful to define intermediate outcomes that take you towards that goal. This keeps things realistic and avoids discouragement. It can also align the scope of a project to resources (time, money, people, data, technology) constraints.

Finally, as GEOGLAM CapDev interventions often take place in a "project framework," it may be that your project's funding agency has already defined the long-term impact. Even in this case, it is still very important to implement this step and organise a consultative process with the funder to re-confirm the already-defined impact and adjust or refine it if necessary.

Be as specific as possible. Avoid "mega-impacts" which are big, complex, and unlikely to be achieved in one intervention. Avoid vague impacts which lead to fuzzy thinking about what needs to be done to reach them and will be impossible to measure.[15]

Step 3: Developing the Strategic Pathways

The ToC is the conceptual model supporting the impact way of working. Once the ToC has been discussed, developed, and, ideally, presented as a narrative for a specific CapDev intervention, the different steps from activities to the higher-level impact need to be described and operationalised. The logical sequence of these steps is the so-called Strategic Pathway.

What is a Strategic Pathway? Strategic Pathways are the logical steps towards achieving the expected impacts of a CapDev intervention over time, beyond the duration of the intervention or project. The design of the Strategic Pathways is a **backward process** that focuses first on *what we are going to achieve* before we outline *what we are going to do*. First, it presents the wider scientific, economic, and societal impacts of the project. Then, it continues with the outcomes corresponding to the preconditions required to bring about the impact. Finally, it describes the outputs, activities, and inputs. Figure 5 presents the different levels of a Strategic Pathway.

Outcomes: The expected effects of a CapDev activity in the short, intermediate, and long term. They relate to the changes in behaviour, relationships, actions, and activities of stakeholders, resulting from the exchange of knowledge and the uptake of the project outputs. Depending on the type of outcome, they may occur rapidly (immediate or initial outcomes), within the project's duration or after the project has ceased (intermediate and long-term outcomes). Outcomes lead to impact and change.

When developing your Strategic Pathways, it is important to identify and discuss similarities in identified "intermediate outcomes" and "initial outcomes" and reduce complexity where possible. Iterate until you think that all of the sufficient and necessary conditions for all eventual outcomes and impacts have been identified. In the end, it must tell a clear story of what outcomes are needed to reach your identified impacts.

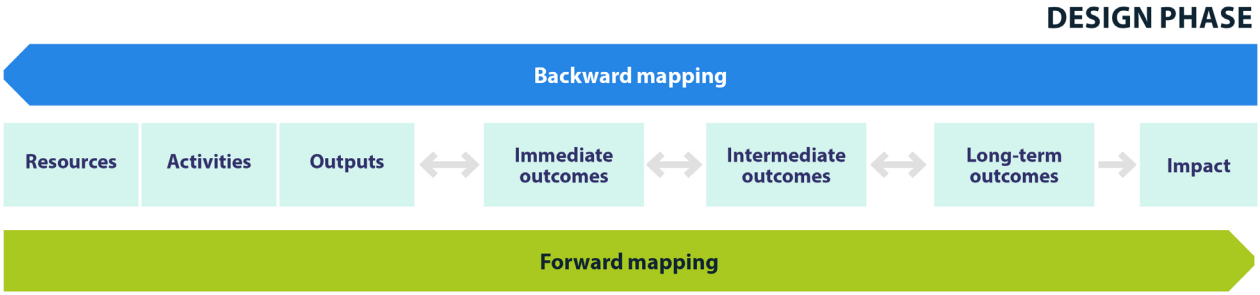


Figure 5 - A Strategic Pathway based on the Theory of Change (source: J. Teuben - ITC workshop on impact)

Keep it focused and simple. First, it is important to focus on the most immediate preconditions to reach the long-term impact and consider them in relation to other desired outcomes. We recommend **limiting the number of outcomes to between four and six**. Having more than that will make the mapping process overly complicated, and your final Strategic Pathway will be difficult to implement.

Answering the following questions will guide you in developing outcomes:

1. Which stakeholders play a role and which changes are needed?
2. Who must do what differently to achieve the desired priority outcomes?

These questions can be answered in a "Stakeholder Mapping" Tool 3: section D—this is a useful tool that will allow you to better understand the roles, influence, or interests the different stakeholders might have in achieving the desired outcomes and impact. In the end, your Strategic Pathways must tell a clear story of what outcomes are needed to reach your identified impacts.

Each stakeholder needs to recognise themselves in your planned outcomes and impacts. GEOGLAM projects often combine a variety of stakeholders who might have agendas and visions that do not align with one another. For instance, a GEOGLAM project may develop a crop mapping service for a given Ministry or Department while simultaneously planning to rely on another Ministry or Department to collect data on the ground (e.g., Statistical Offices, Paying Agencies, etc.). It is not obvious that these two stakeholders know that they are working towards the same long-term impact. For instance, using ground data collected for statistical purposes in a crop mapping service is not straightforward because the sampling has not been designed for such use. In this case, ensure that your outcomes make sense for your different "categories" of stakeholders. The success of your project will largely depend on how much your stakeholders recognise themselves (their roles and their objectives) in your long-term impact and related outcomes.

Before implementing a change in the Strategic Pathway, be sure all partners agree to it. As the facilitating partner, you might be tempted to refine the Strategic Pathway. In this case, you need to strike a balance between the benefit of an improved framework and the risk that the remaining partners lose their stake in the project. Before starting a new session, it will be important to explain the changes that you made and reach agreement by all partners. This is an essential part of co-creation.

Strategic interventions

Once the outcomes have been described, the Strategic Pathway must be completed by focusing on the strategic interventions, which are the concrete deliverables of your CapDev project, including insights, tools, services, publications, etc. In this step you can finally think about the outputs, activities—such as training—and the inputs needed to conduct those activities.

Outputs: What is generated during the project implementation. This may include, for example, enhanced knowledge through training and coaching, innovative (digital) solutions, guidelines, demonstrators, databases and datasets, awareness training, etc. Outputs lead to outcomes.

Activities: What you practically carry out during the CapDev intervention. Activities lead to outputs. (Tool 4: Section D)

Inputs/resources: Precursors to your CapDev intervention. They include financial, technological, data, institutional, human resource, contextual, and even relational resources and capacities needed to undertake a CapDev intervention. The activities you undertake are guided by the inputs available.

Why is it important? Firstly, Strategic Pathways focus on the goal of CapDev—having an impact. While they can have scientific impact, typically they have societal impact. Scientific impact happens due to knowledge creation. Societal impact happens through knowledge utilisation. Thus, having impact means that there has been a change due to utilising new knowledge.

Second, it provides an evidence-base for evaluating what you did to achieve that impact. This evidence means you can Monitor, Evaluate, and Learn (MEL) throughout your CapDev intervention (see 2. Developing And Deploying A Continuous Monitoring, Evaluation, And Learning System: Section D).

Why is it useful? By developing Strategic Pathways and using the MEL tools, you can determine what difference you made and how you made it as a result of your CapDev intervention. This will enhance your organisation's ability to develop more effective activities, achieve better outcomes, and have a bigger impact in the future. In essence, it develops your own capacity to be effective and impactful partners in a co-creation CapDev relationship. It is also useful for stakeholders and funders because you can clearly show them the actions that you took and how those steps led to outcomes.

There is no one-size-fits-all solution. When defining your Strategic Pathways, keep in mind that there is no single solution that will fit all needs or all groups of actors. Tools and activities must be diverse, and you must also offer certain flexibility to adjust them during the process. Ideally, they should build on existing workflows (organisational, technical, etc.) and use resources that are already in place.

The following questions will guide you in developing strategic interventions:

1. What outputs—insights, knowledge, tools, etc.—are needed to achieve the desired outcomes?
2. What are the activities needed to achieve the outputs?
3. What are the resources—financial, computational, infrastructural, and of course human—needed to conduct these activities?

3. Assumptions

Assumptions are assertions that something is true where we do not feel the need to question or check whether they are true. Assumptions are strongly associated with our beliefs and values and are often personal. Every stakeholder has their own values and their own assumptions. When identifying the impact of a CapDev intervention, you need to consider the context, actors, and factors at play as well as the assumptions surrounding each of those considerations. Making these assumptions explicit—in a stakeholder workshop as part of the ToC development—will lead to more effective teamwork through increased understanding and improve the design of your intervention.

Some of the key questions to ask when making assumptions about stakeholder values explicit are:

1. What, according to the experience of stakeholders, is influencing the current situation?
2. What are the norms and beliefs held by involved individuals?
3. What are the needs, motivations, behaviours, or capacities of the involved individuals?
4. What are the interests and roles of involved individuals, and what are the relations between them?

Assumptions must also be made about the Strategic Pathways—you assume that project resources (inputs) will lead to project outputs, which will result in project outcomes, which will in turn lead to societal impacts.

Critical reflection on these assumptions include:

1. What are the assumed causal relations between activities?
2. Which strategy do we think will work (i.e., which strategy is effective, relevant, feasible, and sustainable)?
3. What are the effects of specific strategic choices?
4. What are the conditions required for change to happen?
5. Is there evidence to supports the validity of these assumptions?
6. What are the risks and how severe are those risks if our assumptions are invalid?

4. Visualisation of the strategic pathways

Different Strategic Pathways might be needed to achieve the envisaged impact. However, budget or time limitations might force you to select just one or two Strategic Pathways. However, by identifying all Strategic Pathways, you gain a complete understanding of the current problem's complexities and the importance of seeking alliances with other stakeholders who are capable of conducting one of the other Strategic Pathways.

Figure 6 shows the Strategic Pathway model and the connections and assumptions between the different levels.

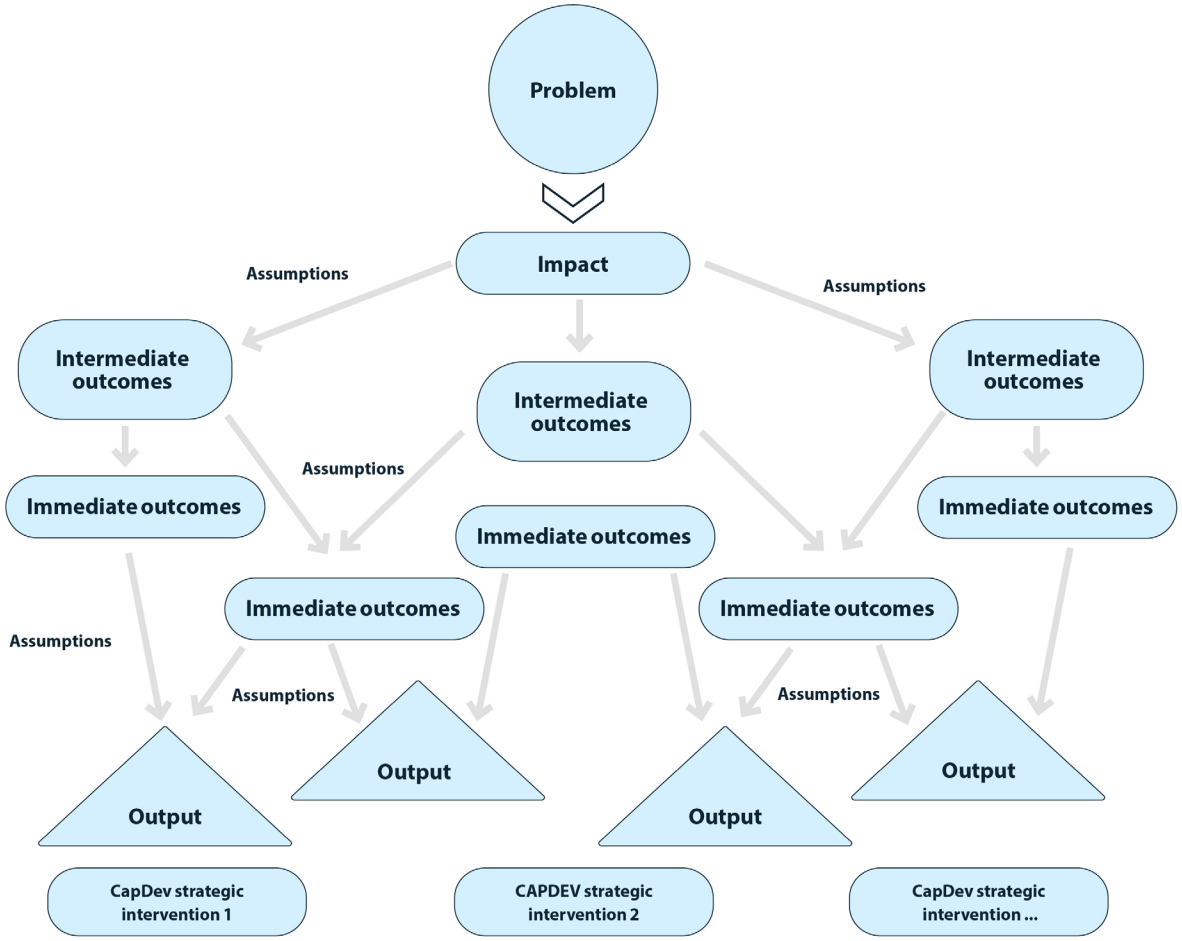


Figure 6 - Strategic Pathway model (J. Teuben)

D: Practice and tools for co-creating impactful CapDev interventions

We show six useful **Tools** to use when co-creating impactful CapDev interventions

1. **Preparation** to understand the problem, the user demand, and the target audience
2. How and when to conduct a **User Needs Assessment**
3. How and when to conduct a **Stakeholder Mapping** or **Analysis**
4. Examples of CapDev **Activities** and **Modalities**
5. Developing **Indicators** to measure progress towards outcomes and impact
6. Implementing a **Review** and **Reflection** of your Strategic Pathway

We then describe why and how to develop and implement a continuous **Monitoring, Evaluation, and Learning** system during your intervention

1. Tools for creating CapDev interventions

Tool 1: Preparation

It is helpful to do some homework before starting to implement your CapDev intervention. The less you know about the group(s) you will be working with and working for, the more preparation you will want to do. Make sure you have a good understanding of the situation (current situation, problems, key actors, and factors at play, etc.). Try to meet the key players in advance and look for bilateral meeting opportunities.

Box 3: Preparation checklist: engaging and establishing a co-creation relationship

- Starting from a demand-side ("target audience") should drive the work. This is key to establishing trust.
- Those on the supply-side or pre-transition side should have relevant expertise and understand what is technically feasible.
- Do not over-promise on EO capabilities.
- Understand the target audience organisation. Work with a champion within that organisation who can commit time and mobilise resources internally.
- Understand how the organisation's decision-making process currently works (including where they sit in the decision support system), and how new information/data/tools could fit and enrich.
- Be upfront about where EO fits and the likely continuity of the EO data being provided.
- Situate the EO-based solution within the realities of the organisation's local IT/internet infrastructure.
- Understand and if useful, engage the organisation's network. Local organisations, universities, and companies can be a source of resources for expansion and sustainability.

(Source: NASA Harvest)

Tool 2: User needs assessment

A User Needs Assessment aims to identify users' interests, needs, requirements, and knowledge gaps—this information is used to tailor the CapDev intervention. An effective assessment will help direct you to the areas of greatest demand. It also supports one of GEOGLAM's principles: leveraging existing capacities. It aims to identify and understand the "gap" between what is currently known/available and the desired knowledge, skills, and abilities needed to achieve the final outputs and change. A User Needs Assessment involves the following steps.

1. **Identification of the different target audiences that will benefit from the CapDev intervention.** What are the main characteristics of the audience (technicians, mid-level management, higher management, policymakers, decision-makers, etc.)? What is their interest? What is their current experience?
2. **Characterisation of the status of usage of EO by the target audience.** Do this both broadly and specifically to the impact sought.
3. **Collecting information on previous CapDev interventions for the target audience.** Have previous CapDev interventions taken place? By or with whom? What were the outcomes? What does the target audience have to share about those experiences?
4. **Developing the consultation process.** How are you going to conduct the User Needs Assessment? What are the tools and data collection approaches? Who to address, by whom, when, and how?
5. **Conducting the consultation process.** Collect and analyse all relevant inputs. Review the responses of the target audience, analyse the data, and describe the main conclusions.
6. **Sharing the outcomes.** Transform the assessment outcomes into a draft proposal about your CapDev intervention to be shared and approved by the target audience.
7. **Use the outcomes as input for the Strategic Pathways.** The outcomes provide a clear picture of the problem to be solved and the impact to be achieved.

For a more profound description of a User Needs Assessment, we refer to the SERVIR Service Planning Toolkit Needs Assessment Guide, Version 1.0.

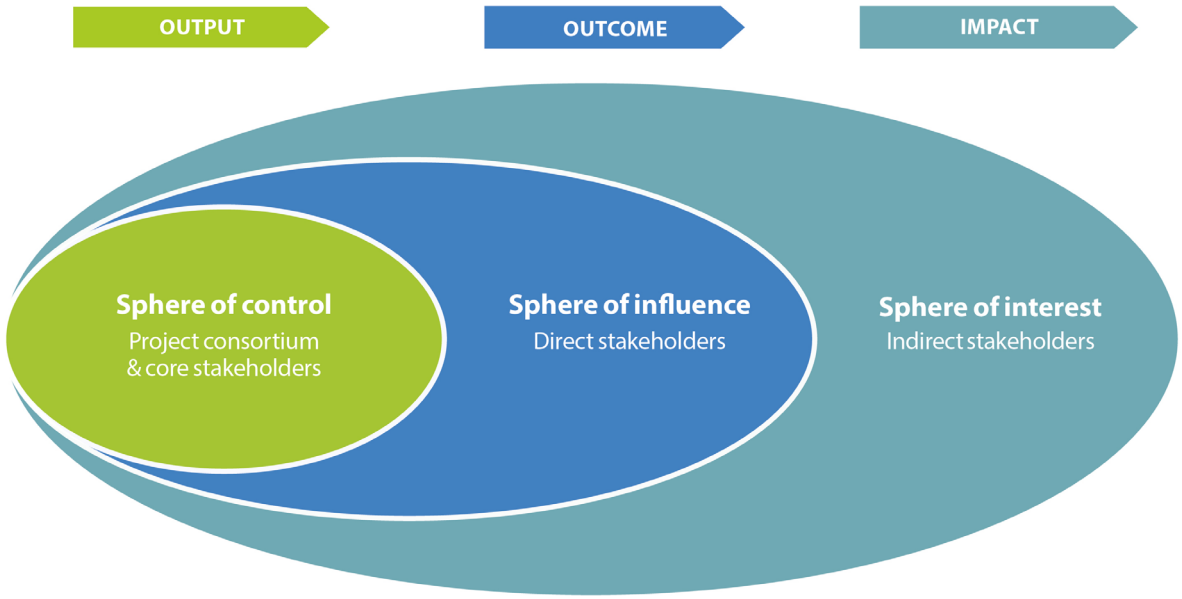


Figure 7 - Stakeholder Mapping (HIVOS ToC Guidelines, 2015)

Tool 3: Stakeholder mapping

When one organisation or group of participants is the target audience for the CapDev intervention, a User Needs Assessment will be sufficient to obtain the necessary information to design the CapDev intervention. However, when many audiences are involved, an additional step of a stakeholder identification and assessment exercise may be needed. This is especially relevant when the CapDev intervention focuses on a larger group of actors or institutions, all of whom are part of a broader organisational ecosystem. In this circumstance, it is essential to identify the role those critical actors play in the workflow, information, and/or decision that the CapDev intervention aims to change; the power and influence they have to do so; and the interest they have in changing it. This allows for diverse perspectives, skills, expertise, preferences, and "ways of knowing" to be considered in the co-creation process.[16]

In line with the SERVIR Service Planning Toolkit, we identify three points in the project timeline to conduct the Stakeholder Mapping exercise:

1. During the User Needs Assessment, to pinpoint the outline of the CapDev intervention.
2. During the design process, to refine the understanding of the stakeholder environment, ensure stakeholder engagement, and identify which institutions and individuals are critical to achieving impact.
3. In developing baselines for MEL, particularly as an input to a Theory of Change (Section C.1).

Your Stakeholder Mapping exercise can be done by the design team. This process will consist of organising and categorising an initial stakeholder list, checking the completeness of the stakeholder list, and visualising the roles and relationships among the stakeholders. It is sometimes helpful to group stakeholders based on their level of control, influence, or interest concerning the CapDev intervention and the phase of the Strategic Pathway they are engaged in (Figure 7).

The **Sphere of Control** refers to everything that the project has full control over and is fully responsible for. This includes the inputs, activities, and outputs as well as the quality of activities, products, and engagement with stakeholders and other actors. Typical actors in this sphere are the implementation partners of the CapDev activity and the beneficiaries/end-users.

The **Sphere of Influence** refers to the outcomes the project expects because of its activities, including how stakeholders and other actors in the context use and/or respond to the outputs of the action. National agencies, NGO's, and statistical agencies—which are supposed to use the outcomes of the CapDev activity for decision-making and supporting the expected impact—must be considered in this sphere.

The **Sphere of Interest** is the sphere of lasting, structural change—changes in the lives of people and in conditions in society. It represents long-term changes beyond the control of any single actor or factor. In a ToC process, the desired change is often formulated at this level or at the level of (indirect) outcomes. The communities at large and grass-root organisations are typical actors in this sphere as well as policymakers on national and international levels.

Tool 4: Example CapDev activities and modalities

There are many possible activities within a CapDev project. Table 1 provides examples of CapDev activities, different formats or modalities to consider when designing them, and factors to be aware of when deciding which modality is most suitable for your purposes.

Table 1 - Examples of activities and modalities

ACTIVITY	MODALITIES (EXAMPLES)	NOTES
Support Enabling Conditions On An Organisational Level	• Leverage existing capacities to support the adjustment of policies and regulations. • Identify champions that are well-established in the organisation. • Establish networks of accountability with clear responsibilities at the outset of the project.	
Training	• Seminars or webinars (finite topical synchronous or asynchronous trainer presentations). • On-the-job training (hands-on, long-term, synchronous exchange). • Workshops (dedicated synchronous events with defined skill-development outcomes).	The choice of modality is dictated by the specific focus (thematic or methodological) and desired learning outcomes: • **General awareness** (e.g., general EO methods and tools) • **New datasets or technologies** (augmentation or addition to existing knowledge) • **Specific skill development**
Tool Documentation	• Development of manuals, guidelines, training materials, demonstration datasets, tutorials, videos, etc. • Distribution and storage in a common repository for easy re-use.	These tools must be used as an extension or continuation of prior of trainings, as their objective is to empower ongoing independent learning "at the office." When possible, it can be useful to provide the infrastructure where the learning can continue (e.g., mobile app for field data collection, test environment for IT and EO knowledge, etc.).
Continuous And Regular Assistance And Advice	• Networks for interaction: online user groups are particularly valuable where there are multiple users of the same system/tool. • Check-ins at regular intervals between partners. • Organisation of interactive activities (e.g., webinars, newsletters, side-events at larger meetings).	Trainings are limited in duration—no matter the quality of documentation, questions will always arrive. Continued support beyond the lifetime of a project is critical to sustained EO adoption. The aim of these activities is twofold: (i) to allow stakeholders to give feedback and ask questions and (ii) to allow stakeholders to share their experiences with each other (not only with the trainers). These interactions initiate problem-solving discussions within the group and contribute to building a community spirit.
Develop A Plan For Long-Term Stewardship	• Create an accountability plan for data and services (e.g., software updates).	An important note for funders and project leads: Stewardship of a project's outputs beyond its lifetime should be maintained insomuch as human and financial resources allow. Allocating for low-cost-extension of the project's outputs in the form of web-presence maintenance and technical support beyond the core of the project's timeline is strongly encouraged.

Tool 5: Indicators

CapDev is a continuous and evolving process of growth and positive change (impact). Here are some examples of impact relative to addressing problems that have been posited by GEOGLAM partners in their work. These are provided to illustrate the broad types of impact that GEOGLAM partners have had or aim to have, and provides a point of reference for framing interventions:

- **Human impact**: population impacted by application/decision; quantifiable or characterizable reduction in mortality or livelihood risk; reduction of vulnerability/increase in adaptative capacity.
- **Biophysical impact**: increasing crop/rangeland productivity; reducing input requirements; better natural resource management; increasing soil health.
- **Financial impact**: helping the end user by reducing monitoring/measurement/assessment costs; increasing agricultural productivity/profitability; decreasing price volatility.
- **General societal benefit**: reducing degradation or other negative externalities; mitigating climate change; increasing ecosystem services; amassing new knowledge.

Defining concrete indicators of a project's impact relative to addressing problems is challenging—the outcomes from our strategic interventions can only be assessed in the long-term and in the context of broader activities and interventions. Within a project, however, a more useful approach is the definition of qualitative indicators of progress toward outcomes and outputs. These indicators should be at the level of outcomes and outputs (section C.2, Step 3), and be designed to measure progress against the conditions at project initiation (baseline) throughout a project's lifetime.

Quality over quantity: GEOGLAM experience has broadly demonstrated that aiming to meet quantitative indicators of outputs in an impact-driven approach is often the incorrect level to place emphasis. For example, it may be that one well-designed tool or product effectively delivered to/with a few well-positioned partners in the requestor organisation can get us much closer to desired outcomes and impact than a multitude of tools delivered to many trainees. The aim with indicators is to measure what counts, rather than counting what you can easily measure.

While **quantitative** indicators are often prioritised by funding organisations, we nevertheless encourage an emphasis on **qualitative** indicators that are supported, as needed, by well-designed quantitative indicators. As a reminder, someone may reference their Theory of Change to clearly identify their need for quantitative indicators vs. qualitative indictors in charting their Strategic Pathway.

When relevant, try to define the status of your indicator(s) to be used as a baseline when assessing progress. Ensure the indicators are SMART:

Specific: firmly related to the defined output or outcome as well as clearly and unambiguously formulated.

Measurable: the unit of measurement is defined (qualitatively or quantitatively).

Achievable: the change anticipated should be achievable by the project relative to the baseline for the indicator at project initiation.

Realistic: the set target values for the indicators should be ambitious yet realistic.

Time-bound: there is a defined timeline to achieve the indicator.

Box 4: Examples of qualitative and quantitative indicators at different levels

Examples of qualitative indicators on outcome level:

- National agency provides the information, tools, etc. to their departments.
- Policymakers or other end-users use the information for decision-making.
- National agency will host the system and their capacity has been improved to use the system.

Examples of quantitative indicators on outcome level:

- In the case of new products, number of new applications using your new products.
- In the case of a system/toolbox, number of concrete adoptions (or tests if you offer some testing environment).
- Number of users able to share experience with the group.
- Number of communities or individuals benefitting from the information provision.

Examples of qualitative indicators on output level:

- The assessment results of the training and training providers have been positive.
- Stakeholders support the co-development of the toolbox.

Examples of quantitative indicators on output level:

- Number of use cases/applications supported by your activities.
- Number of new products, new methods, new toolbox available through your activities.
- Number of versions of the system developed in your activities.
- Number of participants/institutions in your trainings.
- Number of peer-review publications (by your group but importantly, by your users).
- Number of downloads of a new product/system/toolbox.

(Source: Adapted from NASA Harvest)

Tool 6: Review and reflection

After defining all of the Strategic Pathway's elements, **ask one participant (or several if you have different audiences in your user group) to write a narrative**, i.e., a kind of executive summary that describes the Strategic Pathway, the major assumptions, and the key interventions that would convince all stakeholders that this ToC can make a difference. This narrative should then be reviewed and agreed upon by all participants. In your last meeting, the whole ToC is assessed to check the underlying logic of the theory against different standards of quality.

Answering the following questions will help you test and confirm the logic of your Strategic Pathway:

Plausibility

- Does the project make sense?
- Is the project in line with the objective of the funding instrument (if applicable)?
- Is the structure logical?
- Are there any big gaps in logic, assumptions, or steps?
- Have risks and barriers been considered?
- Does the Strategic Pathway create a logical and convincing story of how change will occur?

Feasibility

- Is the project realistic within the funding level and timeline?
- Are all important stakeholders on board with their roles and those of the full project team?
- Does the project team have the capacities and resources to achieve the outputs needed to produce the outcomes in the Strategic Pathway? Do we need additional partners?
- Does existing science indicate that it is possible to generate the outputs?
- Do we need to re-adjust the scope?

Testable

- Are the indicators clear enough to enable progress monitoring towards the long-term goal?

Assumptions

- Are they still valid?
- Does sufficient evidence exist to sustain the assumptions?
- Are there possibilities to mitigate some of the (negative) assumptions?

2. Developing and deploying a continuous monitoring, evaluation, and learning system

A Monitoring, Evaluation, and Learning (MEL) system (Table 2) is an integrated part of the Strategic Pathway that supports the impact-driven approach of CapDev interventions. It is a collection of tools that are used at different stages of your intervention, and it complements the six tools in section D.1. MEL is a continuous process in project or programme execution used to keep track of achievements that lead towards the expected impact or changes. Examples of MEL activities are progress reports which can be combined with an external or peer review, all based on the ToC and Strategic Pathway. The key to a successful MEL process is continuous self-assessments. These self-assessments (joint exercises of teams and stakeholders) include outlining the progress towards outputs and outcomes as well as a reflection on, or revision of, the ToC—this includes its initial assumptions and the Strategic Pathway. It is important to realise that revisiting the ToC will reveal improved understanding and lessons learned on how change is brought about within and beyond the project's teams.

MEL should be embedded in the concept of a Learning Organisation, which states that every experience is an opportunity to learn, and learning is valuable, continuous, and most effective when shared. A Learning Organisation improves and grows based on its own experiences. The ability of an organisation to learn and adapt is a cornerstone of a holistic approach to CapDev. The capability to adapt and renew requires that people and organisations learn from experiences, share information, and improve themselves. Therefore, the outcomes of the MEL activities should result

in a reflection on achievements, successes, and constraints, and eventually cause an adjustment of the project workplan and/or ToC.

The MEL system contains tools to be applied during (i) project design, (ii) project planning and implementation, and (iii) project finalisation and impact assessment.

Table 2 - The monitoring, evaluation, and learning system

PROCESS	EXPLANATION
Monitoring	Refers to the routine monitoring (checking) of the resources, activities, and outcomes as well as the analysis of the information collected to guide the implementation phase of the CapDev interventions.
Evaluation	Refers to the periodic (mid-term, final) assessment and analysis of ongoing or completed CapDev interventions.
Learning	Refers to the process through which information generated from Monitoring and Evaluation is reflected upon and intentionally used to continuously improve the ability of the CapDev interventions to achieve outcomes.

Phase 1: Project design

The first reference for the MEL process is the Strategic Pathway which is used to identify relevant data to be collected and to guide the monitoring and evaluation process. In the MEL process, it is crucial to foster collaborative, ongoing engagement with implementation partners, key stakeholders, and beneficiaries through workshops or meetings to develop, review, and update the ToC.

A second reference is the User Needs Assessment. This assessment explains where a target group's capacities stand prior to the implementation of the project. It is important to work from a solid baseline—this is what you will compare your project outcomes with when determining your project's change. Well-developed baselines improve the quality and validity of your MEL system.

A third reference for the MEL process is a Monitoring and Evaluation Matrix (Table 3). This matrix indicates what must be monitored and/or evaluated, when and how it should be evaluated, who should be involved, and who will conduct it. The Monitoring and Evaluation Matrix should be aligned with the qualitative and quantitative indicators.

Phase 2: Project implementation

During project implementation, several tools and instruments can be used to monitor and evaluate ongoing processes. Examples of such tools are:

Activities on an individual level (training, workshops, seminars, etc.)

- Training evaluation (online or paper-based)
- Tracer studies to collect and analyse data repeatedly over time
- Statistical data

Activities on an organisational level (organisational policies/procedures, change processes, strengthening of primary processes, etc.)

- Surveys
- Face-to-face interviews
- Evaluation workshops

Activities on an institutional level (national policy and strategy development, networking, etc.)

- Stakeholder workshops

Table 3 - Monitoring and evaluation matrix

WHAT	HOW	WHO	WHEN	TARGET GROUP

Phase 3: Project finalisation and impact assessment

The (societal) impact assessment should ideally focus on the expected changes defined in the ToC. It should also focus on the project intervention's measurable effects linked to strengthening capacities on individual, organisational, and institutional levels. The ToC and pre-defined indicators on output and outcome level should be used as references. Other references that relate to national or regional agendas can also be used—or even international frameworks (like the SGD's) if appropriate—as required by funding agencies. Tools that can be used during the impact assessment include desk research of (statistical) data or evaluation workshops and stakeholder meetings.

In addition to measuring the progress of our interventions and the achievement of outputs, outcomes, and impact, we must also consider the relevance, effectiveness, efficiency, and sustainability of our programme, project, or CapDev intervention. The questions presented in Table 4 can be used at the beginning of the process to select the most promising Strategic Pathway or at the end to assess the results of the Strategic Pathway.

The Kirkpatrick model is useful when evaluating the results of a specific training activity. It describes four levels of training results.

- **Level 1:** Reaction. The degree to which participants find the training favourable, engaging, and relevant.
- **Level 2:** Learning. The degree to which participants acquire the intended knowledge, skills, attitude, confidence, and commitment based on their participation in the training.
- **Level 3:** Behaviour. The degree to which participants apply what they learned during training when they return to their jobs.
- **Level 4:** Results. The degree to which desired outcomes occur due to the training.

(Source: https://kirkpatrickpartners.com/the-kirkpatrick-model/)

Table 4 - Four criteria for selecting and/or assessing capdev interventions

CRITERIA	HOW THE CRITERIA CAN BE APPLIED TO ASSESS A CAPDEV INTERVENTION
Relevance	How relevant is/was the CapDev intervention in contributing to the achievement of the higher goals or expected impact?
Effectiveness	How effective is/was the CapDev intervention in achieving the expected outcomes (compared with alternative approaches to achieve the outcomes)?
Efficiency	How well do/will the means convert into outcomes? Consider the quantity and time spent as well as the quality the achieved outcomes. *This generally requires comparing alternative approaches to achieving the same outcome.*
Sustainability	Are the outcomes sustained/will the outcomes be sustained after external funding has ended? Pay attention to factors of ownership by beneficiaries, policy support, economic and financial factors, socio-cultural aspects, gender equality, appropriate technology, environmental aspects, and institutional and management capacity.

E: GEOGLAM case studies

The GEOGLAM community has implemented CapDev interventions in diverse projects globally

Case studies from GEOGLAM are presented following the Strategic Pathway approach

By presenting these examples, their impact, and the lessons learned, we aim to inspire and guide practitioners in the design, implementation, and evaluation of their CapDev interventions

This section presents several case studies from the GEOGLAM community, describing CapDev interventions in Africa, Asia, and the Americas. The case studies use a common template that follows the steps outlined in the Strategic Pathway approach section (C.2.). Each case study starts with a clear problem statement and justification of the CapDev initiative. This is followed by the expected impact, the stakeholders and their roles, and the main outcomes and related activities and outputs. Each one ends with a reflection, lessons learned, and outlines opportunities to scale up the intervention.

1. A national crop estimation system in South Africa

Terry Newby, Geoterraimage (Pty) ltd

Problem statement - justification of the Capdev initiative

South Africa is unique in being both an exporter and importer of grain, depending on inter-seasonal climate variability. In 1997, the South African commercial agricultural sector moved from a price controlled single marketing channel to an open free market agricultural system. This triggered the Department of Agriculture's need for a sustainable operational national crop estimation system to ensure price stability and equitable marketing competitiveness. The system needed to be accurate, timely, reliable, objective, and affordable.

The (expected) impact of the Capdev initiative

Price fluctuations due to a lack of market intelligence (i.e., crop size) can negatively impact food affordability and food security. Reliable and timely crop estimates stabilise markets and resultant food prices. This initiative will allow the provincial departments of agriculture and the national government to provide the required intelligence to the government, market stakeholders, farmers, and consumers to facilitate price stability and provide an early warning of food insecurities.

The stakeholders involved and their roles

National government (agriculture) provides resources and utilises the generated intelligence for food security policy. The provincial government provides resources and supports stakeholders with information. Market stakeholders and farmers utilise the intelligence for market strategies, import/export decisions, and production/planting decisions.

The main outcomes of the Capdev initiative

Informed decision-making by all role players, a levelled playing field for marketing, and price stability.

Concrete activities and outputs

An integrated national operational crop estimation system that is recognised as scientifically sound, unbiased, and trusted by all role players in the value chain.

Evaluation, reflection, and lessons learned

The project went operational shortly after proof of concept in 2000 and has been continually improved to date. The estimates have consistently achieved close to prescribed accuracy criteria (Figure 8). In addition, the developed system has proved adaptable for other agricultural and natural resource surveys. In a modified form it is used to monitor alien woody invader vegetation in South Africa's Range lands and water catchment areas (see page 26 of this online report).

The system is fully described in Crop Yield Forecasting: Methodological and Institutional Aspects – Chapter 4 (UN-FAO 2016). The protocols and operating procedures for the system are held by the National Crop Statistics Consortium (NCSC). It is envisaged that the system will in future be transferred and implemented by provincial agricultural administrations as well.

1. The need to match the system to the expectations, resources, capabilities, and culture of the beneficiaries. The system design was innovative in the use of observers in ultra-light aircrafts which reduced costs without reducing the sample size. It also addressed resistance to on-farm access and interview refusals while maintaining accuracy specifications. The aerial observations were critical (and the most cost-effective method) for statistical sampling, training data for crop type satellite image classification and accuracy verification.
2. Rapid operational progress can be made if a continual improvement approach is adopted. The next improvement to this system will be implementing yield estimates based on Earth observations in place of costly in-field surveys.

Opportunities for up-scaling or out-scaling

The system can be operationalised at district, provincial, and national scale in all regions/countries where agricultural production estimates are required.

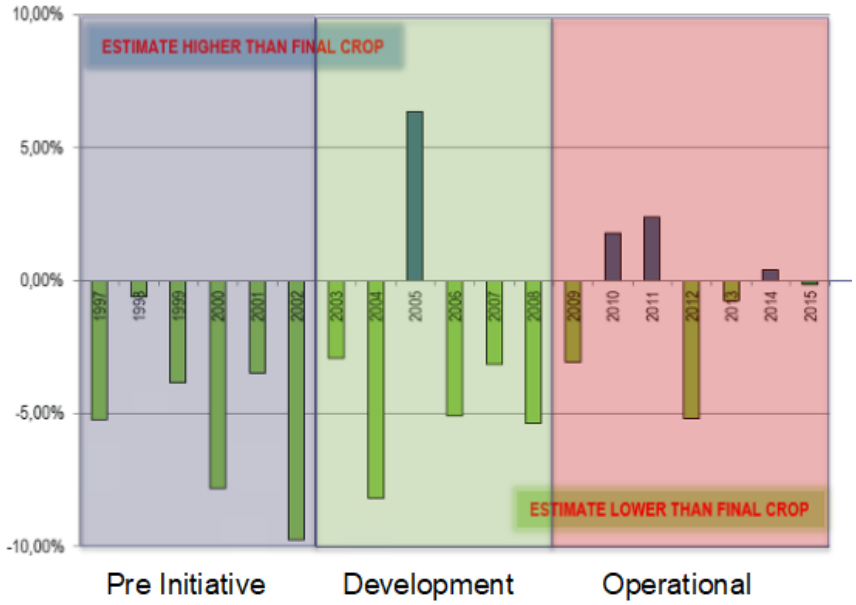


Figure 8 - Years in which the crop was estimated to be above/below actual. Note the decrease in both variance and number of above/below estimates once the system became operational (Source: E du Preeze, SIQ).

2. The Disaster Risk Financing Program in Uganda

Catherine Nakalembe, University of Maryland/NASA Harvest

Problem statement - justification of the Capdev initiative

Vulnerable households in Uganda face considerable climatic risks, primarily related to drought. Uganda's predominantly rural population mostly consists of smallholder farmers who are subject to several production constraints and have limited capacity to cope with recurrent climatic shocks. The Karamoja region is particularly vulnerable to food insecurity. More than 80 percent of households in the region rely heavily on rainfed, low-productivity subsistence crops. Due to poor and sporadic rainfall the region is highly exposed to droughts. Recognising this, the Ugandan government included a Disaster Risk Fund (DRF) component in the Third Northern Uganda Social Action Fund (NUSAF III) program. DRF provided additional support to NUSAF beneficiaries in the Karamoja region immediately following crop failure—due to agricultural drought—through a temporary expansion (or 'scaling up') of Labour-Intensive Public Works activities. This additional support in times of crisis is intended to safeguard development gains made under the broader NUSAF project which would otherwise be lost.

The (expected) impact of the Capdev initiative

Remote sensing data was identified as a critical component for triggering the DRF. This ensured that a reliable metric was used to determine the severity of drought across NUSAF beneficiaries and that additional resources would be released as quickly as possible following the onset of a drought event. Capacity development under DRF was to ensure the Office of the Prime Minister's Department of Disaster Preparedness and Management in the National Emergency Coordination and Operations Centre (NECOC) were equipped and ready to utilise satellite, ground, and other data to support the scaling process.

The stakeholders involved and their roles

The University of Maryland's (Technical support) data analysis determined the threshold for scaling up. The University also aided in developing the Crop Monitor System, training NECOC to utilise the Global Agricultural Monitoring (GLAM) system, and training field officers to utilise an open-source mobile data collection platform (ODK) for data collection. NECOC created the data analysist compilation and developed DRF reports. The Ministry of Agriculture, FAO, WFP, FEWSNET, and Makerere University all served on the technical advisory committee, supported ground assessments and provided additional data/evidence.

The main outcomes of the Capdev initiative

NECOC was able to independently and successfully analyse data on a monthly basis to produce the technical reports required for the success of the program (Figure 9). The team also managed field extension officers' data collection campaigns with extension agents who provided monthly ground evidence of crop conditions. To date, NECOC continues to operate and publish the UNIEWS bulletin—the Official Government of Uganda inter-ministerial/agencies monthly national integrated, multi-hazard early warning bulletin—that includes a crop monitor report and GLAM analysis across the country.

Between 2017 and 2020, US $14M of financing indirectly benefitted 90,405 households in north-eastern Uganda. Over the four years, the early financing release saved the government roughly US $11M in reactive food aid costs. The Earth observation-based early warning system has helped vulnerable households and enabled the government to plan its budget and ensure that resources are utilised efficiently and effectively.

Concrete activities and outputs

Multiple capacity development training on the utilisation of EO tools and Data including GLAM. Tools for ground data collection (OpenDataKit) and ultimately the development of the Uganda Crop Monitor system. To date, OPM utilises the GEOGLAM Crop Monitor and GLAM for tracking and reporting crop conditions in the UNIEWS bulletin (Figure 10).

Evaluation, reflection, and lessons learned

The success of this work was largely due to working closely with partners who benefited directly from the tools—this scenario addressed major gaps in a program that our partners were investing in. Also, supporting similar efforts as opposed to "capacity development for capacity development's sake" pays off the most.

Opportunities for up-scaling or out-scaling

The system can be operationalised at district, provincial, and national scale in all regions/countries where agricultural production estimates are required.

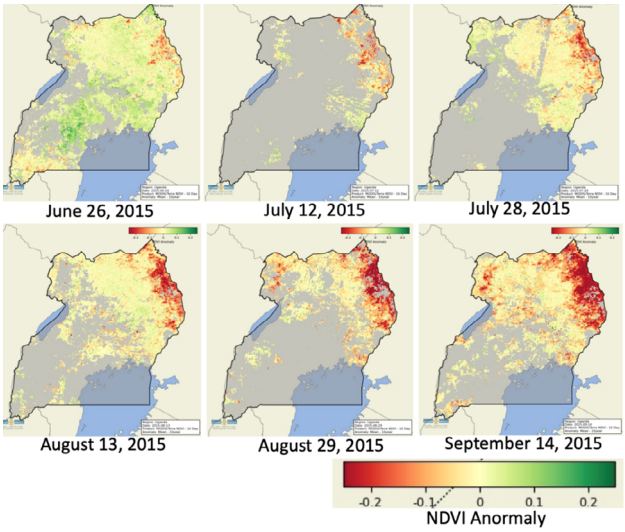


Figure 9 - Crop conditions across Uganda, showing deterioration of crop conditions (represented by NDVI) in Karamoja (top right corner) through time (June to September 2015); Source: GLAM

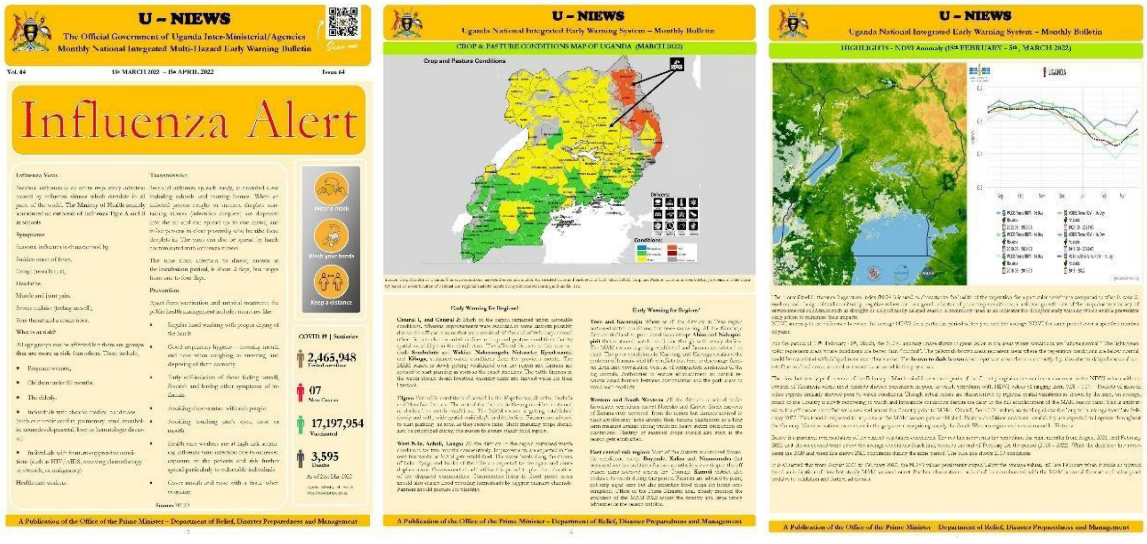


Figure 10 - The Official Government of Uganda Inter-Ministerial/Agencies Monthly National Integrated Multi-Hazard Early Warning Bulletin -- Page 2 Crop Monitor Report and Page 3 GLAM based summary. SOURCE NECOC

3. Development of the agriculture watch platform For East Africa

Maria Dimou and Felix Rembold, Joint Research Centre of the European Commission, Directorate D - Sustainable Resources, Food Security Unit – D5

Problem statement - justification of the Capdev initiative

The Eastern Africa region has a highly variable climate and is prone to climate extremes such as droughts and floods that exacerbate food and water insecurity. A system that provides early warning information on food production anomalies because of climate variability and extremes is particularly relevant with the increasing frequency of climate extremes caused by climate change. The COVID-19 pandemic further increases the need for information due to restricted access to remote areas as well as to the additional monitoring needs for understanding the impact of the pandemic on agricultural livelihoods.

The importance of Earth observation technologies in both large-scale monitoring and hotspot monitoring of crop and rangeland conditions is growing with the rapidly evolving availability of satellite imagery and access to cloud computing services. The derived information provides a relevant contribution to food security assessments and therefore early warning information for early action. The capacity for Earth observation technology use in developing countries is increasing—there is a high demand for international cooperation to build on what is working well, adapt and customise it, and to accomplish these goals without re-developing everything from scratch.

The (expected) impact of the Capdev initiative

The Agriculture Watch Platform is an online decision support system for early warnings about hotspots of agricultural production anomalies (for crops and rangelands) in East Africa. We expect the platform will be used for food security crises prevention and response planning anticipation. It will inform existing working groups that meet regularly to update the latest climate hazard and food security vulnerability information and share that information with the humanitarian aid community (e.g., the Food and Nutrition Security Working Group (FNSWG).

The stakeholders involved and their roles

The Intergovernmental Authority on Development (IGAD) Climate Prediction and Applications Centre (ICPAC) is one of the regional implementing centres of the Intra-ACP Climate Services (ClimSA). Agriculture monitoring is one of the thematic applications that ICPAC is implementing. The platform was developed as part of the Intra-ACP Climate Services project in collaboration with the Joint Research Centre of the European Commission (JRC). In particular, the Agriculture Watch Platform fits well in a suite of different geospatial services that ICPAC is developing for its Member States, called the East Africa Hazards Watch. Another stakeholder is the FNSWG to which the platform was presented. Indirect stakeholders are agricultural analyst in the region. Interest has been shown by various NGOs.

The main outcomes of the Capdev initiative

The East Africa Agriculture Warning Explorer is based on near-real-time Earth observation and weather information and provides automatic ten-day drought condition warnings for crops and rangelands at the provincial level. This information and the indicators used are made available as maps and time series statistics in an interactive GIS environment (Figure 11) to agricultural and food security analysts. The information is synchronised with the JRC's ASAP Warning Explorer.

Because ICPAC is a regional centre, the capacity will be made available through them to single member states. Through capacity development activities, member states will gain the knowledge and skills to analyse and interpret information, derived from the platform, to be used for early warning activities in the region.

Concrete activities and outputs

The East Africa Agriculture Warning Explorer was launched at the 57th Greater Horn of Africa Climate Outlook Forum (GHACOF) in 2021. A Training of Trainers was organised in the first week of February 2021, followed by an extended training to ICPAC Member States representatives in June 2021.

The ICPAC communication department conducted an awareness campaign of the system that took place as a Project Update of the Intra-ACP project and shared on various online platforms (ICPAC Website: Latest News; Data Centre Page of ICPAC; Mailing Lists: a) Agriculture and Food Security and b) FSNWG; Social Media: ICPAC's twitter account; "EA Agriculture and Rangelands" Telegram channel). A special awareness event was co-organised with major NGOs. An analytics component will be implemented to monitor usage of the site.

Evaluation, reflection, and lessons learned

The exercise was successful in the sense that it provided the right technology and support when it was requested by the main stakeholder (ICPAC). The stakeholder was fully in charge of the integration into their own project portfolio, training activities, and the integration of the technologies used in their existing environment.

Among the lessons learnt is the fact that relying on the main stakeholder for integrating the offered support in their existing activities worked very well. The same is true for the services and the awareness raising. However, in some cases some redundancy could be perceived among services offered by different international projects, different donors, space agencies etc. A resulting recommendation is that GEOGLAM could further expand its guiding and coordinating role in the field of Earth observation for agriculture and food security early warning.

Opportunities for up-scaling or out-scaling

The next steps include further collaboration between the JRC and ICPAC not only for capacity development but also for improving the operationalisation of the system. Further improvements to the platform are under discussion based on the feedback of users. Some examples of the improvements of the platform are the refinement of the spatial scale to the GAUL2 level (Global Administrative Unit Layers) and the implementation of ICPAC's forecast products in the platform. Moreover, ICPAC, together with the regional partners, are working on a regular bulletin based on data taken from the platform (the bulletin is not yet operational).

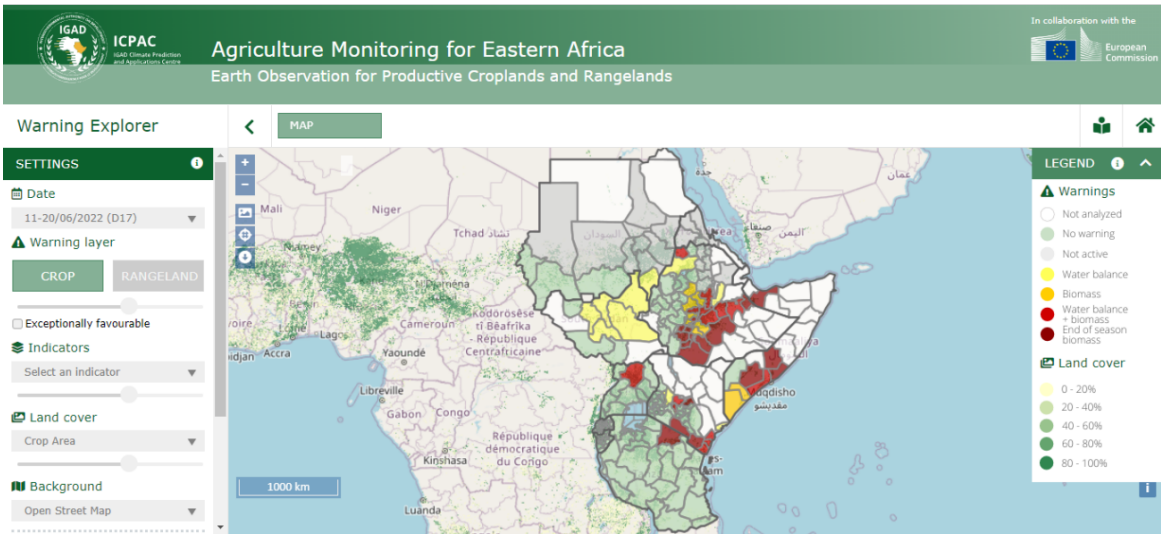


Figure 11 - Interface Of The East Africa Agriculture Warning Explorer Platform

4. Capacity development to produce the agro-meteorological bulletin for Angola

Maria Dimou and Felix Rembold, Joint Research Centre of the European Commission, Directorate D - Sustainable Resources, Food Security Unit – D5

Problem statement - justification of the Capdev initiative

Two-thirds of the population of Angola depend on agriculture for food, income, and employment, and more than half of Angola's poor are in rural areas and depend almost exclusively on agriculture for their livelihood. As the country has only one main cereal cropping season that extends from October to April, it is important to have timely information on the progress of crop and rangeland development. Additionally, the southern part of the country is vulnerable to drought, making agricultural monitoring based on agrometeorological and Earth observation data a relevant contribution to food security early warning.

The (expected) impact of the Capdev initiative

Meteorologists from the Instituto Nacional de Meteorologia e Geofísica (INAMET) in Angola are expected to gain knowledge and understanding regarding the use of Earth observation data for monitoring agricultural production anomalies (for both croplands and rangelands). This knowledge will be transformed into a bulletin (produced periodically) that will include information on the monitoring of crop and rangeland conditions for major cereal producing provinces or provinces that experience recurring droughts.

The stakeholders involved and their roles

The production of bulletins and capacity development activities are taking place under a collaboration agreement between the JRC and INAMET. Members of the D5 unit of the JRC are supporting and guiding meteorologists from INAMET in using JRC's ASAP Warning Explorer to produce the bulletins.

The Food Security unit of the Ministry of Agriculture of Angola will also be involved with the contribution of agricultural statistical data and other relevant information. Indirect stakeholders are all the recipients of the bulletin, meaning agricultural and food security analysts, policy makers, researchers, and farmers.

The main outcomes of the Capdev initiative

Recurring droughts and extreme weather events often affect the agricultural season. It is therefore necessary for farmers to have up-to-date meteorological information to take preventive measures on time. Moreover, when policy makers—members of the Ministry of Agriculture—have the latest information regarding the impact of the weather events on the progress of the agricultural season, they can provide support and relief measures to the farmers, sufficiently early in the season.

The information regarding the progress of the agricultural season and the extent of the impact of extreme weather events can be provided with an agro-meteorological bulletin. The bulletin includes, for selected provinces, a detailed analysis of rainfall estimate patterns based on Rainfall Estimates from Rain Gauge and Satellite Observations (CHIRPS) data in connection with available weather station data, and the development of vegetation conditions in cropland and rangelands based on the temporal profile and detected anomalies in normalised difference vegetation index (NDVI) time series data.

The source of the data is mainly the JRC's ASAP Warning Explorer, complemented with information from weather stations provided by INAMET. The ASAP (Anomaly Hotspot of Agricultural Production) is an online web application integrating several Earth observation datasets to identify anomaly hotspots in crop and rangeland areas. JRC and INAMET are working closely together for the planning of the bulletin (the provinces to be analysed, the publication dates, etc.) and for the detailed analysis of the data taken from ASAP's warning explorer and INAMET.

Concrete activities and outputs

The first agro-meteorological bulletin was published in mid-May 2020, reporting crop and rangeland conditions on three southern provinces (Namibe, Huila, and Cunene) for the agricultural season between October 2019 and April 2020. The second agro-meteorological bulletin was published in mid-July 2020, covering four central provinces (Huambo, Bié, Cuanza Sul, and Benguela) for the agricultural season between October 2019-May 2020. The next agro-meteorological bulletin was published in the end of February 2021, covering again the three southern provinces of Namibe, Huila, and Cunene for the agricultural period between October 2020-January 2021. Finally, the latest agro-meteorological bulletin was published in the beginning of July

2021, providing information for the progress of the 2020/2021 agricultural season in the southwestern part of the country that was affected by the worst drought in 30 years (Figure 12).

Between the various publication's dates, training activities took place between JRC's Food security analysts and INAMET's meteorologists in order to support INAMET scientists with the use of the JRC's ASAP Warning Explorer as well as the interpretation of the data and the various indicators.

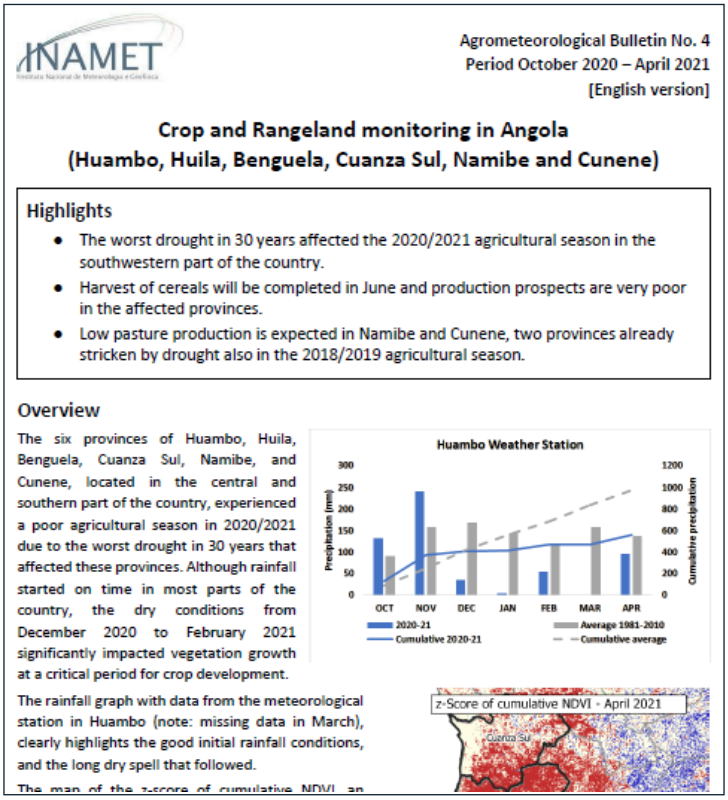
Evaluation, reflection, and lessons learned

The initiative was successful in the sense that four bulletins were released, providing useful information regarding food security analysts, policy makers, and farmers. Some of the bulletins were even featured in a local newspaper. The latest bulletin provided information on the progress of the 2020/2021 agricultural season in the southwestern part of the country that was affected by the worst drought in 30 years, and it was well received from analysts from the FRESAN (Fortalecimento da Resiliência e da Segurança Alimentar e Nutricional) program in Angola.

Among the lessons learned is the fact that there was a lack of familiarity with remote sensing data and indicators due to the scientific background of the scientists of INAMET. This means that the capacity development needs for acquiring and interpreting Earth observation data are high for them to be fully independent in producing the bulletin.

Opportunities for up-scaling or out-scaling

Cooperation between JRC and INAMET, providing continuous support with tutorials and guidance with the target of making the analysts of INAMET fully autonomous in the production of the agro-meteorological bulletins continued after the production of the latest bulletin for some time. The latest published bulletin is available here (in English): https://mars.jrc.ec.europa.eu/asap/files/INAMET_bulletin_04_en.pdf. However, in the course of 2022, the bulletin was discontinued and the role of guidance and assistance for the production of agrometeorological bulletins was transferred to FRESAN/IPMA.



INAMET

Agrometeorological Bulletin No. 4
Period October 2020 – April 2021
[English version]

Crop and Rangeland monitoring in Angola
(Huambo, Huila, Benguela, Cuanza Sul, Namibe and Cunene)

Highlights

- The worst drought in 30 years affected the 2020/2021 agricultural season in the southwestern part of the country.
- Harvest of cereals will be completed in June and production prospects are very poor in the affected provinces.
- Low pasture production is expected in Namibe and Cunene, two provinces already stricken by drought also in the 2018/2019 agricultural season.

Overview

The six provinces of Huambo, Huila, Benguela, Cuanza Sul, Namibe, and Cunene, located in the central and southern part of the country, experienced a poor agricultural season in 2020/2021 due to the worst drought in 30 years that affected these provinces. Although rainfall started on time in most parts of the country, the dry conditions from December 2020 to February 2021 significantly impacted vegetation growth at a critical period for crop development.

The rainfall graph with data from the meteorological station in Huambo (note: missing data in March), clearly highlights the good initial rainfall conditions, and the long dry spell that followed.

Figure 12 - Part of the 4th bulletin covering the period October 2020-April 2021

5. CropWatch For Enhancing Food Security Governance In Mozambique

Hongwei Zeng, Bingfang Wu, and Miao Zhang, CropWatch, Chinese Academy of Sciences

Problem statement - justification of the Capdev initiative

Mozambique faces serious food insecurity challenges due to frequent extreme climatic events, underdeveloped infrastructure, and rapid population growth. Mozambique's Ministry of Agriculture and Rural Development (MMARD) releases monthly meteorological bulletins during the rainy season providing information on weather risks to crops.

Earth observation technology has the potential to support decision making in MAARD as part of their crop monitoring system, but there is a lack of access to and use of Earth observation data in MAARD. In a co-development activity with Mozambique, the China CropWatch Cloud platform has been modified to meet national needs along with technical training to strengthen crop monitoring capacity in the country.

The (expected) impact of the Capdev initiative

Timely and accurate information on crop growth conditions and production plays a critical role in crop early warning, agricultural management, and food import policies. This initiative will customise an agricultural monitoring system for MAARD to fill the information gap for policymakers.

The stakeholders involved and their roles

The CropWatch Cloud platform was customised in a co-development process. The in-situ data collection, model calibration, and validation were jointly done by local experts from MMARD, the Universidade Católica de Moçambique (UCM), and the CropWatch team. MAARD and provincial agricultural administrators provided the training facilities, personnel, and coordination support to the initiative. USM provided the training and field trip survey support. The CropWatch team provided the IT and training support.

The main outcomes of the Capdev initiative

This training and customised platform have enabled MMARD to monitor national crop condition independently since 2018, directly addressing the prior lack of national agronomic information. In 2019, CropWatch Cloud for Mozambique was selected as one of the best "rural solutions" by the International Fund for Agricultural Development (IFAD) due to its contributions in improving the capacities of Mozambique to access domestic and global agricultural information.

Concrete activities and outputs

The CropWatch-Mozambique Cloud-based platform was developed (Figure 13 left) following a series of discussions with experts in Mozambique. Technical staff from the MMARD and all provincial agricultural administrations participated in training on the use of CropWatch-Mozambique for agricultural monitoring at the national scale and provincial levels. After a series of trainings held in Mozambique and China, technical staff were able to independently monitor the agricultural situation and make their analyses at various scales from national to sub-national levels. These systems successfully address the gap in agronomic information in the Mozambique National Agro-Meteorological Bulletin. Since June 2018, the agronomic information from this system has been incorporated into 18 national agriculture and meteorology bulletins, providing scientific support for decision making in Mozambique.

One issue was the lack of spatially detailed cropland information. Experts from the CropWatch team, MMARD, and UCM jointly worked together and produced 10m resolution cropland data at 10m for the entire country (Figure 13 right), which was independently validated by MMARD and had on overall accuracy 83.8%.

Evaluation, reflection, and lessons learned

A cloud-based architecture was adopted to develop a one-stop solution for agricultural monitoring and food security early warnings for Mozambique. A member of the Department of Crops and Early Warning in MMARD said "Our team has been applying CropWatch-Mozambique to generate monthly agriculture bulletins during the rainy season, which informs policy making at national and provincial-level agriculture departments." The Minister of MMARD specifically requested that the CropWatch team expand its technical trainings to cover all districts and further provide cloud services in crop forecasting and early warning.

In terms of lessons learned, the functions and modules of the monitoring system should be designed in a friendly and flexible way that can easily be upgraded based on the expectations and requirements of users in the target country. In this case, we deployed the system on the Ali cloud platform without hardware and storage investments in Mozambique. We adopted an online shopping approach to provide module customisation services to MMARD staff which facilitates their own agricultural monitoring and food security early warnings.

Finally, capacity development activities face many challenges such as language barriers, unfamiliarity with Earth observation and related technologies, and financial constraints. Successful capacity development requires well targeted, well organised, and systematic training activities.

Continuity

We continue to work jointly on crop type mapping in Mozambique's major crop-producing area to provide more accurate monitoring information for particular crops.

Opportunities for up-scaling or out-scaling

The cloud-based platform can be tailored for other countries.

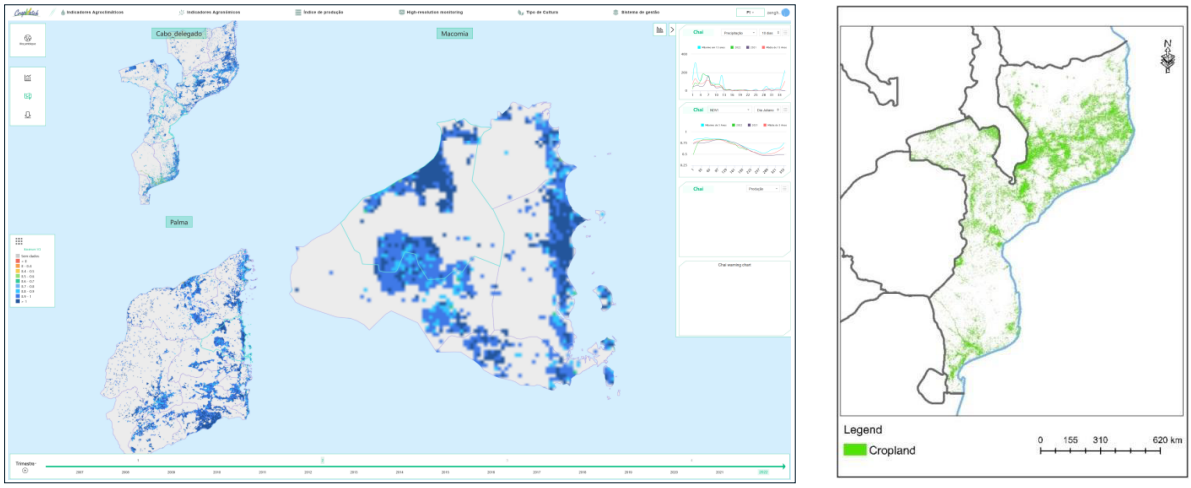


Figure 13 - Cropwatch For Mozambique (Left); Cropland Data At 10m Resolution (Right)

6. Development Of An Online Agricultural Water Accounting Platform

Sven Gilliams, VITO, Belgium and Livia Peiser FAO, Italy

Problem statement - justification of the Capdev initiative

Agriculture is a key user of water. The sustainable use of this important resource will be a major factor in achieving food security in the future. Thanks to the availability of open and free data sets, FAO and its partners were able to develop a methodology and a platform to carefully monitor water productivity in agriculture.

The (expected) impact of the Capdev initiative

FAO's portal to monitor Water Productivity through Open-access of Remotely sensed derived data (WaPOR) is intended to create an action framework that provides relevant and specific information on water and biomass status for stakeholders at different scales—from the policy level to the farm level—to develop solutions that sustainably increase agricultural land and water productivity.

This portal assists countries in monitoring water productivity, identifying water productivity gaps, proposing solutions to reduce these gaps, and contributes to the sustainable increase of agricultural production. At the same time, it takes into account ecosystems and the equitable use of water resources, which should eventually lead to an overall reduction of water stress.

The stakeholders involved and their roles

By providing near-real-time information, WaPOR opens the door for service providers to assist farmers in obtaining more reliable yields and improving their livelihoods. At the same time, irrigation authorities have access to information that can aid in modernising their irrigation schemes, and government agencies can use the information to promote and increase the efficient use of their natural resources.

The main outcomes of the Capdev initiative

The portal provides an assessment, in space and time, of agricultural water and land productivity, productivity gaps, and capacity development to close these gaps. Next to this there is the dedicated capacity development of stakeholders to increase water productivity in a sustainable manner.

Concrete activities and outputs

The development of a portal to monitor Water Productivity. Using remotely sensed data, this portal covers Africa and the Near East to monitor agricultural water and land productivity in near real time as well carbon dioxide uptake by vegetation.

Capacity development is a key element to enhancing knowledge about water productivity and developing the skills to use the WaPOR portal. This provides governments and farmers with the appropriate tools to support decisions and targeted interventions using more efficient water use. This was done at two different levels: at field level and national level.

A series of capacity development activities targeted at national stakeholders—including representatives from Ministries of Agriculture and Environment, Academic and Research Institutes, River Basin Authorities—have been organised by FAO in collaboration with IHE-Delft. The objective of these activities was to share the concept of water productivity and the use of the WaPOR portal to provide governments with the appropriate tools to support decisions and targeted interventions related to more efficient use of water.

At field level, three sets of activities were organised:

- Identifying the relevant stakeholders and undertaking a stakeholder needs assessment.
- Identifying current ICT activities and other possible solutions in agricultural water management and undertaking capacity development with identified partners.
- Developing, designing, piloting, and evaluating potential solutions to increase water productivity in a sustainable manner.

These activities are aimed to identify possible solutions to improve water productivity, and to generate best-practice lessons and learning materials that can be replicated and up scaled in other areas and countries.

Water and land productivity is assessed in a different way for the three spatial levels:

On level I (continental level - 250 m ground resolution), water productivity is monitored in terms of biomass production per hectare per cubic meter of water consumed. A distinction is made between irrigated and rainfed agriculture. Land and water productivity are calculated on pixel basis, which can be aggregated to country or river basin level.

On level II (national and sub-national level - 100 m ground resolution), land and water productivity are monitored for a selected set of countries and river basins while distinguishing irrigated or rainfed agriculture. Land productivity is expressed in terms of yield (kg/ha), water productivity is calculated as production per volume of water (kg/m³). Water used for agricultural production is expressed in actual evapotranspiration, where a distinction is made between evapotranspiration originating from precipitation ("green" water) and incremental evaporation originating from irrigation ("blue" water).

On level III (irrigation scheme and sub-basin - 30 m ground resolution), land and water productivity are monitored for a selected set of irrigation schemes to assess the functioning of the irrigation system and to propose improvements of these systems (Figure 14). On this level, land and water productivity is calculated similarly to level II, but with details on crop type. In addition, economic water productivity for multiple uses of water is assessed in terms of economic return per amount of irrigation water used. Water productivity plays a central role in the performance assessment of irrigation which is the basis of irrigation modernisation. After modernisation of an irrigation scheme, the water services provided to all water users should be more reliable, more cost effective, better adapted to increased climatic variability due to climate change, and more environmentally friendly.

Evaluation, reflection, and lessons learned

A participatory methodology review process has provided the opportunity to collectively prioritise improvements of WaPOR. Validation assessments carried out by different research institutions (IHE-DELFT, University of Twente) and feedback received from users has helped define priorities for improvement of the WaPOR.

Continuity

The current version (WaPOR 2.0) launched in June 2019 during the celebration of the World Day to combat Desertification and Drought.

Opportunities for up-scaling or out-scaling

Currently WaPOR offers more than ten years of near-real-time data from 21 parameters. The approach developed within WAPOR is scalable, however one needs to keep in mind specific data requirements per level. For the most detailed level (level III) the in-situ data requirements for parameter production are much higher than for level 1. But all methodologies can be scaled towards larger areas than the current target of Africa and the middle east. Further information about the WaPOR project can be found here and tutorials and webinars are here.

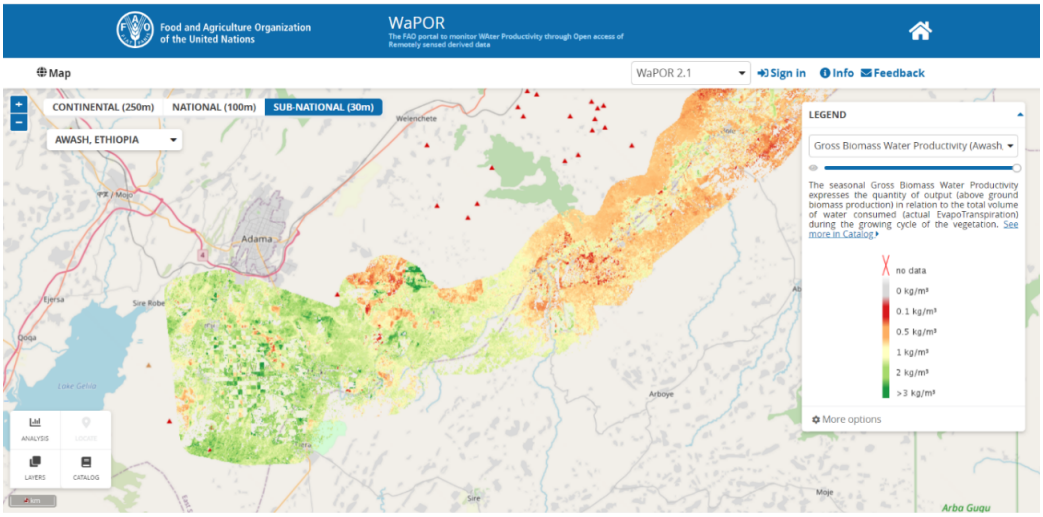


Figure 14 - Wapor Data Base At Level III In The Awash Region Of Ethiopia, Gross Biomass Water Productivity

7. The Redevelopment Of GLAM For Operational Use By Major Production Countries In South America

Alyssa. K. Whitcraft, John Keniston, Estefania Puricelli, and Michael Humber. University of Maryland

Problem statement - justification of the Capdev initiative

Satellite remote sensing allows us to carry out large-scale monitoring of many key agriculture variables through the implementation of objective, timely, and repeatable measurements. Yet, some of those who would derive the most value from remote sensing-derived information are not satellite data experts. Those who are experts often experience challenges in downloading, pre-processing, storing, and analysing large datasets in near-real time. Additionally, the duplicative work of constructing an "analysis ready" time series is an inefficient use of time, particularly as the size of the Earth observation archive increases. Given the importance of within-season agriculture monitoring, these are substantial problems that must be addressed.

To confront these challenges, in the early 2000s the University of Maryland (UMD) together with NASA and USDA developed the first web-based platform to enable near-real-time monitoring of global croplands using NASA MODIS data, enabling operational users across the globe to track crop conditions as seasons unfolded (Becker-Reshef et al., 2009). Known as the "Global Agricultural Monitoring" System (GLAM), it found operational use in global monitoring as well as by national entities in Brazil, Argentina, Mexico, Pakistan, Tanzania, the USA, and others. By 2017, key existing operational GLAM users such as Conab (Brazil) and INTA (Argentina) had developed numerous suggestions for improvement related to new functionalities, new data sets, flexible language use, and a faster and more reliable system.

The (expected) impact of the Capdev initiative

By incorporating additional datasets, improving linguistic translations throughout the system, increasing the availability of tutorials and system manuals in multiple languages, increasing system processing speed, and iteratively reviewing the new interface with experienced and novice users throughout the system redevelopment, NASA Harvest expected that the new "GLAM 2.0" system would not only better meet the needs of Conab and INTA, but also open up opportunities for new users to integrate this system and satellite Earth observations for agricultural decisions, in line with GEOGLAM's broad purpose.

The stakeholders involved and their roles

Conab-Brasil (National Company of Food Supply), a public company under the umbrella of the Agriculture Ministry, Livestock and Food Supply, has been an active participant in the GEOGLAM G20 initiative. They collaborate monthly with the GEOGLAM Crop Monitor for AMIS (CM4AMIS) and share data and experiences through "Agricultural Monitoring in Americas" (AMA), a joint GEOGLAM- AmeriGEO regional initiative. For a decade, Conab (under Divino Figueiredo) has utilised the GLAM system to provide up-to-date information on national agricultural production of major commodity crops to the Brazilian government. All engaged Conab partners are remote sensing experts.

INTA-Argentina (the National Agricultural Technology Institute) is part of the Argentine Ministry of Agriculture, Ranching, and Fisheries, which advances innovation in sustainable agricultural development through research and extension. Like Conab, INTA has been using the GLAM system for their national monitoring and as input to the GEOGLAM CM4AMIS for over a decade. After the departure of INTA's team lead, there was a slow-down in the GLAM-for-INTA progress. However, reengagement with INTA was facilitated by the GEOGLAM Joint Experiment for Crop Assessment and Monitoring (JECAM) operational research and development initiative. Through that, there was a re-review of the prior INTA-GLAM system, provided substantial commentary to improve the system, and have continued as organisational champions for GLAM 2.0. All engaged INTA partners are remote sensing experts.

The NASA Harvest Hub at the University of Maryland are key contributors to GEOGLAM, providing Secretariat support as well as co-chairmanship of the GEOGLAM initiative. In 2018, NASA Harvest secured funding from NASA Earth Science Data Systems Program to migrate the existing system to the Amazon Web Services cloud environment with the aim of addressing the issues of duplicative download, expensive hardware, and slow speeds; this was complemented by NASA Applied Sciences Program funds which were allocated to increase the use of EO data by public and private organisations throughout the Americas (Canada to Chile). NASA Harvest remote sensing and cloud computation experts undertook the technical components of the redevelopment of GLAM, while NASA Harvest's Lead Economist joined the experts (all fluent or native Spanish speakers) in engagement with users.

Both Conab and INTA were drivers of change in the GLAM system. In the context of developing their tailored systems, there arose multiple additional opportunities to include other organisations as both novel users of the system. Those additional insight and needs led to further enrichment of the system for all GLAM 2.0 users. One exemplary new organisation is the Bolsa de Cereales (The Buenos Aires Grains Exchange). The Bolsa is a non-profit organisation that provides information on agricultural and economic activity throughout Latin America with an emphasis on Argentina. They utilise telephone surveys and field data collection to study the evolution of key variables such as sowing progress, harvest progress, growth stages and crop development, and yields harvested, among others. Agricultural economists and agronomics from the Bolsa became aware of GLAM 2.0 after an existing engagement between NASA Harvest and the Bolsa translated into the Bolsa joining the AMA working group. Neither the engaged individuals nor the broader Bolsa had ever used remote sensing in the development of their agricultural estimations.

The main outcomes of the Capdev initiative

The system's value is routinely demonstrated by its users, with Conab and the Bolsa regularly sharing resultant analytics from the GLAM 2.0 system in their official reporting, in their GEOGLAM CM4AMIS workflows, and in their unofficial (e.g., social media, presentations) communications and outreach.

For example, the new GLAM 2.0 system was put to test in 2020 when the COVID-19 pandemic prevented field surveys from being fully collected by agricultural analysts around the world, increasing the value of synoptic satellite remote sensing for agriculture. On 2 June 2020, the AMA working group convened a meeting on COVID impacts on agriculture and agricultural monitoring. NASA Harvest debuted the GLAM 2.0 system in Spanish. Following the call, the Head of Estimations from the Bolsa followed up with the GLAM development team via WhatsApp, wherein a mini one-on-one training on the system was executed. Shortly thereafter, the Head of Estimations tweeted about anomalously dry conditions in an area undergoing wheat planting, which he witnessed through the GLAM 2.0 system. The most important newspaper in Argentina, *La Nación*, picked up the story,[22] and increased attention was placed on mitigating the impacts of drought in the affected regions (Figure 15). In the ensuing months, the Head of Estimations utilised the system to generate official reports,[23] and was able to train a journalist at La Nación on how to utilise the system himself. The reporter has since utilised to report on extended drought conditions in Argentina.[24] Together, these uses demonstrate the value of GEOGLAM networks, and of opportunistic dialogues in bringing satellite data to diverse users.

Concrete activities and outputs

In 2018, the NASA Harvest team travelled to Brazil to meet with Conab and INTA representatives to review the specific requests and co-develop proposed solutions to the system's deficiencies. This in-person meeting was enabled by leveraging the coincident 2018 AmeriGEO conference.

Some requests were specific (e.g., Portuguese or Spanish language translation, flexible cloud cover thresholds, custom time periods for developing measures of central tendency), while other requests only became clear through iterative tweaking and discussion (e.g., appearance and overlay of chart functions). In total, the transition to AWS and the redesign of the system took over two years, as each set of improvements was followed by additional virtual hands-on training on new features and additional listening sessions to understand what worked and what still needed adjustment.

GLAM 2.0 is now a fully global system (Figure 16) with a front end that can be endlessly tailored for each organisation's needs, with customised interfaces, functionalities, languages, and underlying input data (i.e., crop type maps and crop calendars).

Evaluation, reflection, and lessons learned

The success of the GLAM system has been supported by:

- **Long-term relationships:** both before the redesign as well as into the present day, the success of the GLAM system in general and in these instances underscores the importance of long-term engagement, experience sharing, and mutual support.
- **Identifying a champion within each organisation:** For operational uptake of a new technology, data stream, or information source, there must be one or more invested and engaged individuals within participating organisations, particularly the requesting organisation. They are most familiar with their internal organisational context and are the definitive experts on their needs. They are keystones to success.
- **Within-region connections:** Engagement of new users has been facilitated by "early adopters" (e.g., Esteban Copati serving as the liaison to his agricultural economist colleagues, who may not be aware of satellite remote sensing, much less GLAM), as well as through the GEOGLAM and AmeriGEO networks.
- **Formal and informal engagement and communication:** Formal mechanisms, like GEOGLAM and AmeriGEO, empower consistent and structured engagement, which is particularly valuable when there is individual turnover within organisations. Formal workshops and convenings can also greatly clarify the Strategic Pathway

needed to reach the desired impact and address the underlying problem. However, the importance of informal engagement is also underscored in this case study, notably by leveraging social media and communications platforms like WhatsApp, which can foster awareness, collegiality, and very fast action.

- **Ongoing iteration with users:** As mentioned, the redesign of GLAM took nearly two years. This is because of the number of iterations between developers and users necessary to getting the system to where it needed to be for operational use.
- **Cross-pollination between users for an overall enriched system:** Conab and INTA described many similar desired features, but not all were the same. Bringing in agricultural economists with a fundamentally different perspective and set of needs brought a practical lens to the system for meeting non-remote sensing experts. The full system has adopted all these changes, providing benefit to all current and potential users.
- **Conversing in a common language:** Of course, it is not generally possible for all engaged parties to share a common language but having key members of the team able to converse fluently between engaged partners was enormously helpful. Had we had a Portuguese speaker, it would have been even better!
- **Adequate resources:** Such an engagement would not have been possible without the sufficient funds to develop the system and convene the partners.

Opportunities for up-scaling or out-scaling

To date, in addition to the Conab, INTA, and Bolsa instances, GLAM 2.0 interfaces for INIA-Chile and INIA-Uruguay are in development, based on their initial assessment of the global and Conab versions of the system and their own articulated needs. Each system is initialised with the full suite of capabilities that reflect the input of all engaged parties, meaning that the system accrues benefits over time through iterative discussion with an ever-growing user base. In addition to available trainings and manuals, the NASA Harvest team aims to build a Wiki (or other discussion forum) to facilitate discussion directly among users, with publicly documented answers.

The findings from the cloud component of this work were reported to the NASA ESDS team with suggestions for how to ensure cloud-enabled EO analytics be affordable and reliable for future use-oriented systems. Developing the new GLAM system in the Amazon Web Services cloud environment presents an interesting challenge for the continuity of the project—cloud hosting costs need to be continually paid to keep the services operating, whereas the traditional "on-premises" hardware lingers on until it eventually fails. NASA Harvest built an efficient system with the capability of transitioning costs to users, if needed. This is unlikely to be necessary, particularly because costs were substantially lower, with a break-even time of >70 years. Nevertheless, NASA Harvest is seeking opportunities to endow GLAM long-term so that this public good remains available long into the future.

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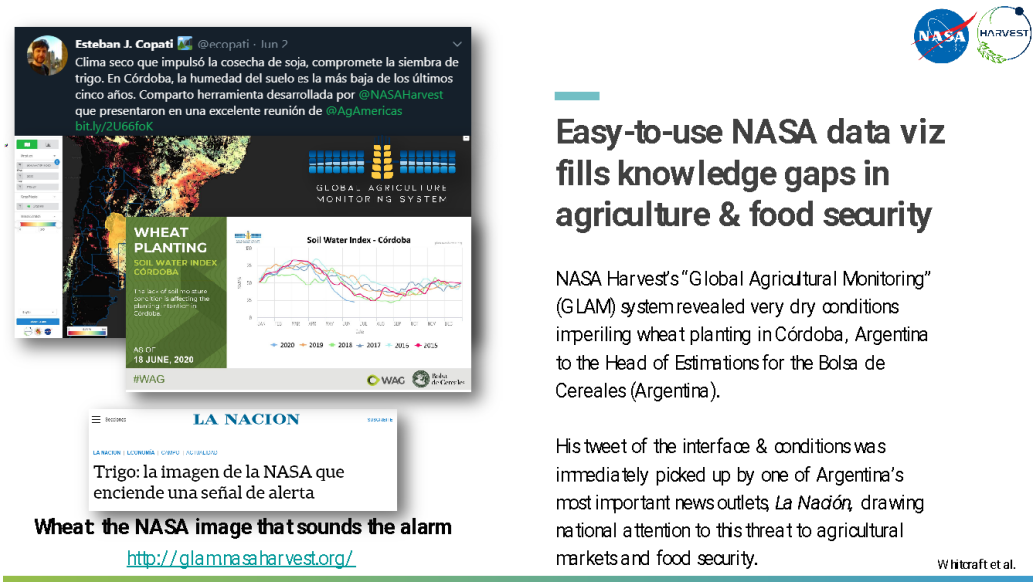

Figure 15 - Media mentions of the GLAM 2.0 system

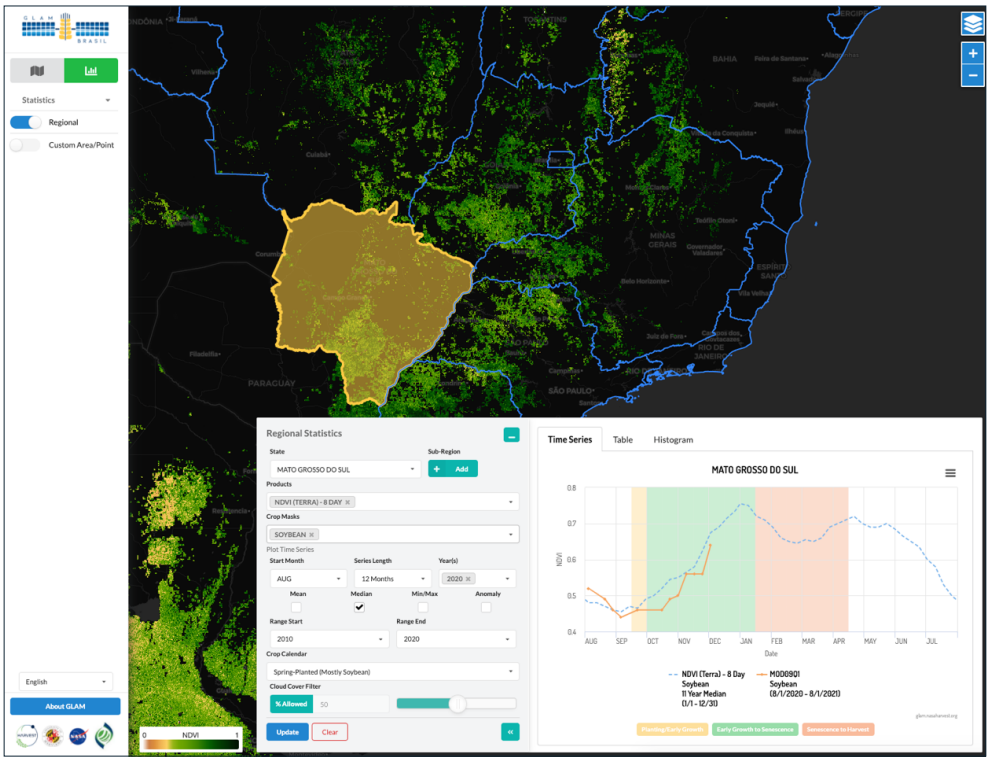

Figure 16 - The Brazilian instance of the GLAM System, showing a plot for soybean in Mato Grosso do Sul for NDVI from Terra (MOD09Q1) 8-day 250m – both the current season (~September 2020 – Present (Dec 2020), and the 10-year median observed soybean NDVI. The plotting interface allows for the overplot of crop calendar information along other utilities to provide context for the user.

8. Joint Workshops And Training Series Involving NASA LCLUC, SARI, GEOGLAM, NASA HARVEST, START, And National/International Partners

Krishna Vadrevu, NASA Marshall Space Flight Center, Huntsville, Alabama and Chris Justice, NASA HARVEST, University of Maryland College Park, USA

Problem statement - justification of the Capdev initiative

The South/Southeast Asia Research Initiative (SARI) is a regional initiative funded by the NASA Land Cover/ Land Use Change program to enhance regional research, education, and capacity building involving state-of-the-art remote sensing, natural sciences, engineering, and social sciences in South/Southeast Asia. Agriculture is one of the important thematic focus areas of the SARI. As a regional initiative with an emphasis on agricultural land use, SARI joined the GEOGLAM Community of Practice. The need for capacity development came from several regional meetings that were organised over eight years in South/Southeast Asia countries. Several SARI meeting participants identified the need for building geospatial capacity in government and academic communities in this region as highly important and useful for research and applications. Specifically, with the rapid development in geospatial technologies, new sensors, algorithms, and cloud computing platforms, regional scientists inferred that there is a strong need to develop good practices for data use and provide necessary training to the local researchers on appropriate spatial technologies useful for agriculture applications. Important training topics include crop condition mapping and monitoring, yield estimation, agricultural drought assessment, crop type, fallow land, and soil mapping. In addition, from the research perspective, robust algorithm testing and validation involving local researchers are very much needed for developing good products. Several of our previous SARI workshop participants urged the SARI team to organise more thematic workshops and training events in the region, which are being pursued in the region.

The (expected) impact of the Capdev initiative

- Increased East-West Research Collaborations and increased use of Earth Observations for national agricultural monitoring.
- Increased capacity building for early career researchers on earth observations data use, tools, and techniques for their career growth.
- Improved capacity for government and non-government personnel to understand the potential of Earth Observations to address agricultural land use/cover changes, mapping, monitoring, production, and yield estimation.

The stakeholders involved and their roles

- Royal University of Agriculture – local host
- NASA SARI – international host and funding
- University of Tokyo Japan – co-host and funding
- National Institute of Environmental Studies – co-host and funding
- 50 (out of 90) in-country participants in the workshop and 50 (out of 70) participants in capacity building training: Cambodia Ministry of Agriculture; Royal University of Phnom Penh, Forest Department, Open Development Cambodia (ODC), several other local universities and NGO's
- 50 participants from other countries: USA, Japan, India, Sri Lanka, Indonesia, Malaysia, Thailand, Vietnam, Laos, Singapore, Nepal

The main outcomes of the Capdev initiative

The Cambodia workshop and training events were organised in August 2022. The primary outcomes included:

- Increased collaborations with Cambodian researchers in Agriculture and other thematic areas (forestry, air pollution, urban, wetlands, etc.) will be useful for building new projects.
- Increased interest by Cambodia's Ministry of Agriculture in the potential use of remote sensing technologies for crop mapping, monitoring, and yield estimation. In particular, the Ministry is interested in crop damage assessment, useful for mitigation efforts and addressing food security issues.

- Early career researchers gained significant novel experience in the use of remote sensing and geospatial technologies useful for their research projects.
- Open Development Cambodia, a non-governmental organisation, showed much more interest in earth observations and data useful for various environmental applications.
- 70 other international participants benefited from improved understanding of Earth observations and the potential for land cover mapping, specifically agriculture.
- A special issue of the Remote Sensing journal was announced in 2022 with Dr. Vadrevu (NASA MSFC), Prof. Justice (NASA Harvest, UMD), and Dr. Gutman (NASA HQ) to help researchers in South/Southeast Asia use Earth observations for var ious environmental applications and land cover degradation, including agriculture. The article processing fee for researchers in South/Southeast Asia has been negotiated with the journal.

Concrete activities and outputs

The workshop focused on identifying needs and priorities for developing remote sensing-based approaches for mapping, monitoring, impacts, and driver assessment of LCLUC specific to agriculture and forestry in South/Southeast Asian countries. Nearly ninety participants from different academic, government, and non-government organisations attended the workshop, and nearly 12 countries were represented. The Royal University of Agriculture (RUA) was the local host. https://lcluc.umd.edu/meetings/international-workshop-land-coverland-use-changes-forestry-and-agriculture-southsoutheast

Followed by the 3-day workshop, a 2-day training event focusing on Remote Sensing and geospatial technologies was organised at the Royal University of Agriculture. Nearly 70 participants from academia, government, and non-government attended the training workshop. The training topics included: a) mapping and monitoring paddy fields using optical and SAR data; b) agricultural land use change mapping using Google Earth Engine training; c) Agricultural water resource budgets using SWAT modelling. The expert trainers were from the USA, Japan, and Thailand.

Evaluation, reflection, and lessons learned

The local host identified the workshop and training topics based on the local need. As a result, the goal and objectives of these events were clear, which helped us better coordination. The workshop and training program were highly successful in bringing together several researchers for effective collaborations and sharing various research experiences and knowledge exchange through case study demonstrations. In addition, the training event was highly successful, with participation from early career researchers and government and non-government personnel. The feedback received from the participants, and our lessons-learned experiences are listed below:

- Integrate a variety of datasets (both optical and SAR). However, considering persistent cloud problems, SAR-based agriculture focused training is preferred.
- Use of open-source tools/software preferred (SARI has made this mandatory, thus, no issues).
- An increase in the training days was recommended; two or three days are insufficient. A week-long training event seems optimal.
- Both the basic and advanced training events on remote sensing and geospatial technologies, catering to diverse researchers, were suggested.
- Focus on the specific thematic topic rather than combining multiple topics (e.g., training on crop type mapping involving multiple crops was recommended, compared to all other land covers).
- Train the trainer approach: to be cost-effective and reduce the financial burden (e.g., food and logistics for 5-days, including travel support for nearly 20 participants, which were provided free for both workshop and training events in our case), the train the trainer approach was recommended.
- Organise more such training events, frequently combining in-person and virtual. However, participants wanted more interactive training events through on-site training.

The training also led to other benefits and spin offs including:

- New project proposals are being developed. We are helping the Royal University of Agriculture researchers' team on a proposal submission for a IUCN CEPF grant. Also, the NASA PEER proposal will be developed for the next cycle to benefit local researchers (if funded).
- A CRC book proposal is in progress wherein several South/Southeast Asia researchers will be helped to integrate remote sensing and geospatial data into their research and published as a book chapters.
- With the feedback from the local researchers, additional capacity-building activities are being planned in the coming months/years in South/Southeast Asian countries (the SARI focus).

Opportunities for up-scaling or out-scaling

The Cambodia workshop and training events were facilitated through NASA funding with co-funding from the National Institute of Environmental Studies (Japan) and the University of Tokyo, Japan. More such events are planned; however, upscaling these events and organising these events more frequently will require additional funding from the US and other international donors.

Figure 17 - SARI workshop participants, Phnom Penh, Cambodia, August 10-13th, 2022. Source: Krishna Vadrevu, NASA MSFC

Figure 18 - SARI training participants, Phnom Penh, Cambodia, August 12-13th, 2022. Source: Krishna Vadrevu. NASA MSFC

9. Monitoring Rice Agriculture Under The Effect Of Climate Change And Anthropogenic Pressures (1)

Thuy Le Toan, Centre d'Eudes Spatiales de la Biosphère, Toulouse

Problem statement - justification of the Capdev initiative

The Vietnam Mekong Delta is one of the regions that is most exposed to extreme events linked to climate change. The frequency, duration, and increased intensity of droughts, floods, and saltwater intrusion, accelerated by human pressures (e.g., exploitation of groundwater and river sand) pose a rising threat to rice production in Vietnam. Faced with the inevitable threat, the Vietnamese Ministry of Agriculture and Rural Development (MARD) and the Ministry of Natural Resources and Environment (MONRE) need to make decisions for resilient agriculture planning. Earth observation was recognised as an essential source of relevant information to support their adaptation and mitigation measures.

In this context, the VietSCO project has been carried out by the French Centre National d'Etudes Spatiales (CNES) in partnership with the Vietnam Academy of Science and Technology (VAST), and as part of the French Space Climate Observatory (SCO) program. The project is focused on satellite monitoring of rice agriculture in the Vietnam Mekong Delta, a priority theme related to food security and socio-economic development in Vietnam.

Using dedicated remote sensing tools developed to monitor rice land, notable changes have been observed in recent years; in terms of rice-growing area, the number of harvests per year, the crop calendar, and the conversion of rice land into other land use types. A WebGIS platform has been developed for stakeholders to observe these changes. These products were developed using Sentinel-1 radar satellite data by CESBIO and GlobEO. They are supplemented by maps of flood, saline water intrusion, and drought for interpretation and analysis. Moreover, projections for the 2050 horizon concerning the areas of rice fields that would be impacted by climate change and human pressure (saline water intrusion, and flooding in particular) have been implemented on the platform, based on recent scientific results in the frame of the GEMMES project (Espagne et al., 2021, Le Toan et al., 2021). The WebGIS platform would thus allow decision-makers to visualise and quantify the losses of rice-growing areas under various scenarios of climate change and resource exploitation.

CapDev has been organised for a) training in rice monitoring using EO data (Sentinel-1) and b) training on the use of the WebGIS platform.

The (expected) impact of the Capdev initiative

Phase 1 of this project has been completed (June 2020-June 2022). The project has created links with different organizations of VAST (VNSC) the Ministries MARD (disaster management centre, statistical centers) and MONRE (National centre for remote sensing). Users' workshops have taken place online in 2021, and in Hanoi in June 16-17, 2022, bringing together academic and user organisations. The participants were very interested in the project outcome, and implementation of VietSCO products was requested by MARD and MONRE in their infrastructure in the future.

The stakeholders involved and their roles

- CNES: Project leader, Management and Funding.
- CESBIO-GlobEO: Technical support, data analysis and interpretation, development of the VietSCo WEbGIS platform, training on rice monitoring using Sentinel-1 Radar data, training users for use of the VietSco platform.
- VAST VNSC: co-project manager, organisation of survey and workshops, responsible of implementation of methods in VAST infrastructure (e.g., the Vietnam Open DataCube in VNSC).
- MARD- CIS: Statistics Office which is interested in monthly rice yield.
- MARD-VNDMA: Disaster Management Agency.
- MONRE NRSD: Remote sending directorate responsible for climate related observations.
- MONRE-IMHEN: Institute of Meteorology, Hydrology and Climate Change: Technical Advisory committee, providing user requirements, additional data, and support ground assessment.

The main outcomes of the Capdev initiative

VietSCO provide the following rice products: monthly rice maps (area, growth stage) and annual rice cropping density (Figure 19), together with dynamic flood extent during the flood season. For visualisation of the impacted rice area under different scenarios of climate change and human pressure, maps of salinity intrusion and terrain elevation are provided (present and projections up to 2050, based on Eslami et al., (2021), and Mindehoud et al., (2020).

Concrete activities and outputs

Tools for rice monitoring and visualisation of the impacts of different scenarios of climate change and resource exploitation (Figure 20) are tested by stakeholders. Multiple capacity development training on utilisation of EO tools and data have taken place. The implementation of the tools is under consideration for Phase 2 of the project.

Evaluation, reflection, and lessons learned

The tools addressed Vietnam's need for estimating the spatial distribution of the impacts of climate change and human pressures on rice production. The tools can be used to assist and support decision makers in their agriculture planning for adaptation and mitigation measures at different scales—from the district to the whole delta.

During Phase 1 of the project, on-the-spot demonstrations and exchanges with partners have been limited due to pandemic. Phase 2 is expected to a) refine the tools to better meet the user needs and b) finalise their operational use, with a focus on the capacity development for adoption of the methods by stakeholders.

Opportunities for up-scaling or out-scaling

Similar projects can be developed, e.g., for the Red River Delta, and for major rice growing Deltas in Asia.

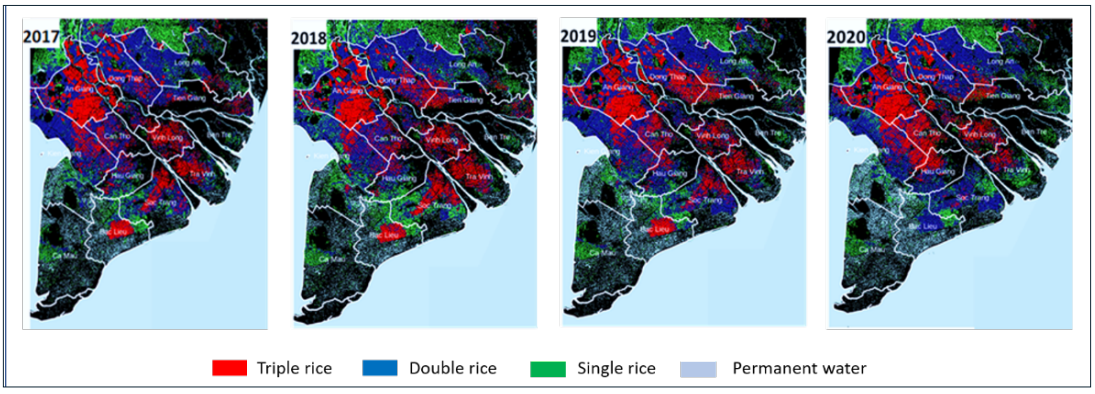

Figure 19 - Observation of rice cropping density in the Vietnam Mekong Delta: Maps of rice areas with triple, double, and single crop in 2017, 2018, 2019 and 2020. From Le Toan et al., (2022).

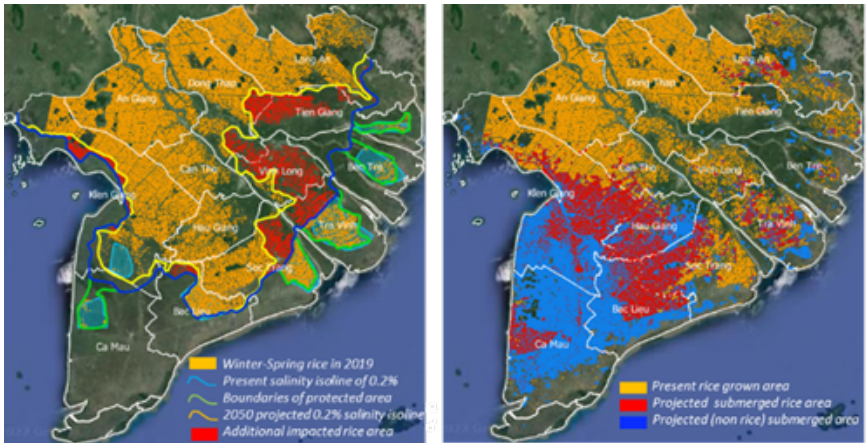

Figure 20 - The Mekong Delta and the risk areas. Left: Projections of salinity intrusions in 2050 in a worst-case scenario (RCP8.5 climate scenario, high subsidence, and riverbed erosion rates [Eslami et al., 2021]) and rice area impacted. Right: Map of the areas falling below sea level by 2050 under RCP4.5 global sea-level rise scenario (+25 cm) and land subsidence triggered by a steady 2%/year increase in groundwater extraction (Mindehoud et al., 2020). From Le Toan et al., (2022).

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10. Monitoring rice agriculture under the effect of climate change and anthropogenic pressures (2)

Shinichi Sobue,[1] Thuy Le Toan[2] and Kei Oyoshi.[1] [1]Japan Aerospace Exploration Agency, Japan;[2] Centre d'Études Spatiales de la Biosphère, Toulouse

Problem statement - justification of the Capdev initiative

Rice is the staple food for more than half of humanity—with 90% of the world's crops grown and consumed in Asia. Global rice production has increased continuously since the Green Revolution. In the same period, the use of chemical inputs, the introduction of modern high-yielding varieties with short growing cycles, and increased access to machinery and irrigation systems have led to a linear growth of crop yields (+0.05ton/ha/year) as well as an increase of the number of crops per year (Food and Agriculture Organization of the United Nations, 2012). Accurate information is needed on the spatial distribution of rice fields, water resource management, risk occurrence, and annual production projections. However, most agricultural surveys rely mainly on statistics based on limited ground samplings at which data are extrapolated to a national scale. Although the census can provide statistical estimates, slow and unsystematic collection of data can limit the ability to make timely decisions. Moreover, rice agriculture is strongly linked to environmental issues, from water management to climate change (methane emission). For these reasons, long term interannual monitoring is also required to study the production and cultural impacts of these factors. Satellite remote sensing can support this long-term monitoring requirement at regional and global scales.

Given the importance of rice, Asian participants in GEOGLAM formed an ad hoc team to ensure the appropriate representation of rice crop monitoring in the GEOGLAM initiative. The goal of Asia-RiCE is to foster the widespread use of EO for "wall-to-wall," whole country, timely and accurate forecasts of rice production at national, regional, and global scales, as an input to the GEOGLAM Crop Monitor and AMIS Market Monitor.

The (expected) impact of the Capdev initiative

The initiative's goal is to strengthen the international community's capacity to produce and disseminate relevant, timely, and accurate forecasts of agricultural production at national and regional scales using Earth observations.

The stakeholders involved and their roles

- Asia-RiCE team: Team Co-leads
- ISRO (Shasharma): VEDAS Agromet information provision
- AFSIS: Rice crop outlooks

The main outcomes of the Capdev initiative

As a result of the Asia-RiCE and SAFE Agromet project collaboration, ISRO's agromet data (precipitation over a wide area) was used in the monthly ASEAN Rice Growing Outlook (RGO) reports published by AFSIS (ASEAN Food Security Information System), in addition to JAXA's agromet data provided through JASMIN system (Figure 21). Training workshops held for the agricultural statisticians of ASEAN countries on the utilization of agromet data have been held using ADB or JAIF (Japan-ASEAN Integration Fund) funds, or in the framework of Asia-RiCE with APRSAF/SAFE projects and AFSIS.

In addition, the Asia-RiCE team provides the following rice planting map products (Figure 22) from JAXA, ESA/CESBIO, and VNSC in cooperation with the ministries of agriculture and space agencies in lower Mekong regions.

Concrete activities and outputs

Asia-RiCE capacity development activities have been organised for a) training in rice monitoring (rice planting and rice outlook) using EO data, and b) training on the use of the ISRO and JAXA agromet information systems, WebGIS platform (WMS/WMTS), and Google Earth Engine.

Asia-RiCE Phase 1A (2013-2014) consisted of four demonstration sites in three countries: Indonesia, Thailand, and Vietnam. Each of these was focused on the development of provincial-level rice crop area estimations. In Phase 1B (2014-2015), additional technical demonstration sites in Chinese Taipei, Japan, and Malaysia were added. Following the successful demonstration of the core functionality of Asia-RiCE, the initiative moved into Phase 2 (2016-2018), which covered: Wall-to-wall SAR observation of selected countries and scaling-up rice crop monitoring using SAR from provincial-level to country/region-level estimates (Vietnam and Indonesia); Expanding rice growth outlooks using satellite-derived agro-meteorological data for Laos, Cambodia, and Myanmar; and continuing rice growth outlooks for FAO/AMIS and related agencies via GEOGLAM in collaboration with AFSIS (ASEAN+3 Food Security Information System). In these phases, all demonstration projects were implemented in cooperation with each country's ministry of agriculture and space agency using EO data, field surveys, and statistical information.

Asia-RiCE Phase 3 (April 2019-March 2021) promoted the use of EO data for wall-to-wall rice crop monitoring in cooperation with GEORICE and international donors; promoted the use of new-generation tools for big EO data analysis, such as the Open Data Cube and cloud-based systems with available data sources and tools (such as INAHOR and GEORICE); continued to promote the use of the Open Data Cube in Vietnam, Cambodia, and Chinese Taipei in cooperation with VNSC, GA, ESA/CNES, NSPO, and JAXA; and continued to promote the generation of rice crop outlooks in Asia using agromet information from Japan (JASMIN) and India (VEDAS). In this phase, the Japan ASEAN integration fund (JAIF), LAPAN, and MOA Indonesia worked to produce rice crop outlook information using agromet data derived from EO for use by ASEAN member states.

In Phase 4 (2021+), with the emergence of SAFE Evolution, Asia-RiCE is reconsidering the role that it plays in this space. AsiaRiCE's connection to GEOGLAM and other international frameworks remains critical, so this will continue to be a key feature and role for the initiative. In this phase, ISRO and JAXA with AFSIS co-host hands-on training regarding Agromet information on VEDAS (in 2022). They plan to have a hands-on training on rice crop planting using INAHOR on Google Earth Engine with ALOS-2 ScanSAR Analysis-Ready Data (ARD).

Evaluation, reflection, and lessons learned

The tools addressed ASEAN's need to estimate the spatial distribution of the impacts of climate change and human pressures on rice production (planting and outlook). The tools can be used to assist and support decision makers' monitoring of rice crop outlooks and production. During Phase 1 of Asia Rice, technical demonstrations at the provincial level were implemented with hands-on training to use ALOS-2 and other data in the INAHOR system to determine rice planting area as well as rice crop outlook using agromet data produced by JAXA/JASMIN in four selected countries in ASEAN. Phase 2 is expected to a) refine the tools to better meet the users' needs and b) finalise their operational use, with a focus on capacity development for adoption of the methods by stakeholders.

Opportunities for up-scaling or out-scaling

Similar projects can be developed not only in SE Asia but also in South Asia and other rice crop regions in cooperation with other GEOGLAM partners.

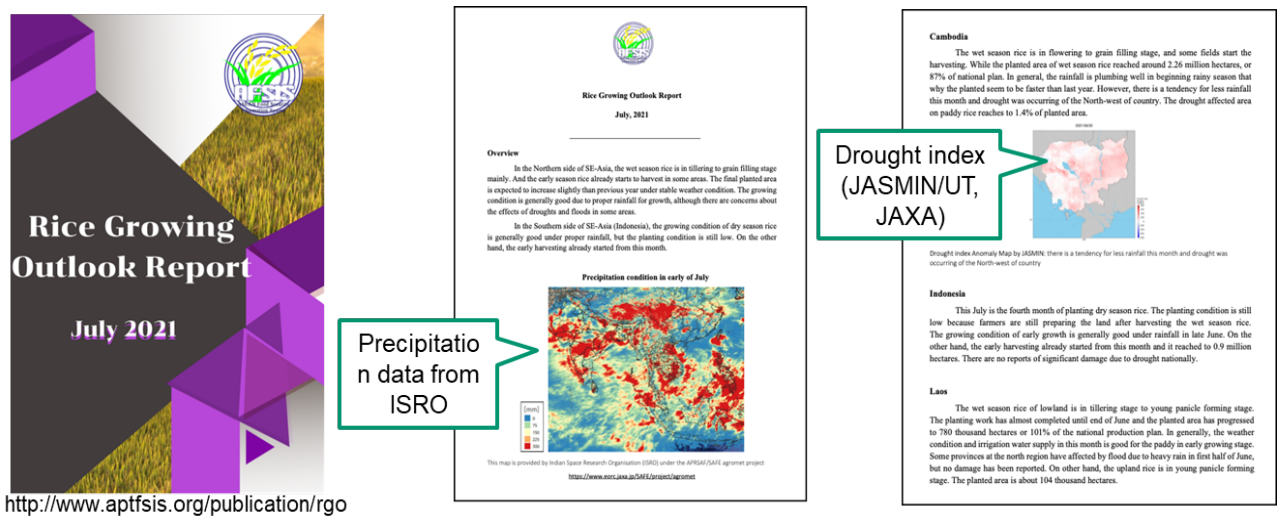

Figure 21 - AFSIS Rice Growing Outlook Reports developed using Agromet information from JAXA and ISRO

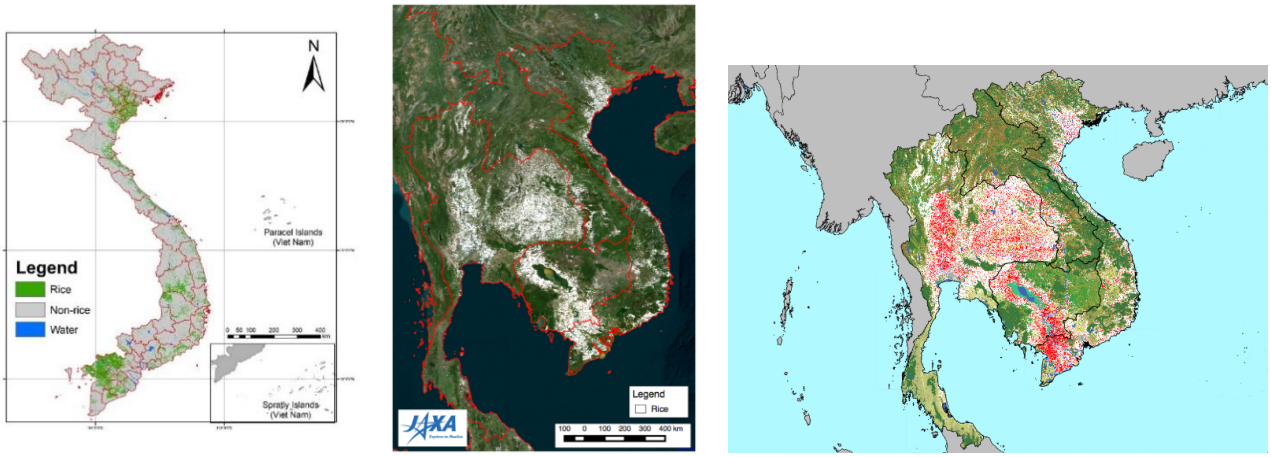

Figure 22 - Rice crop maps (crop season product) of the Mekong area (Cambodia, Laos, Thailand, Vietnam) produced through an ESA GEORice, JAXA and GEO GEOGLAM Asia-RiCE team collaboration.

11. Crop type classification empowers agricultural remote sensing monitoring in Mongolia

Hongwei Zeng, Battsetseg Tuvdendorj, Bingfang Wu, and Miao Zhang. CropWatch, Chinese Academy of Sciences

Problem statement - justification of the Capdev initiative

Wheat is the main staple crop in Mongolia and wheat flour is one of the important ingredients of Mongolian food. Due to climate change, the impact of drought on wheat yield has gradually increased, and successive severe droughts in 2005, 2007, 2010, 2013, and 2015 have significantly reduced wheat yield. Accurate and timely mapping of crop types, especially wheat, is critical to the estimation of crop yield losses due to drought, crop production, and agricultural field management, providing critical information support to agricultural agencies as well as regional agricultural committees to help achieve food security and other related Sustainable Development Goals. However, local governments in Mongolia are still using manual methods to document field properties such as crop type and location, which is costly and time-consuming, resulting in a lack of up-to-date wheat map information in Mongolia.

The (expected) impact of the Capdev initiative

This effort aims to design a crop classification framework in northern Mongolia and to generate a 10 m crop type distribution for Darkhan and Selenge province which is the major wheat-producing area of Mongolia. Such data will support and benefit the localization and customization of a crop monitoring platform for Mongolia, leading to more timely decision making related to food securuty.

The stakeholders involved and their roles

This task was conducted by the United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP), IRIMHE, and the CropWatch team of the Chinese Academy of Sciences. The UNESCAP coordinates the joint activities and the organization of the training course. The in-situ data collection was conducted independently by IRIMHE with GVG tools, an application of a smart mobile phone integrating the GPS, photos, and recording attribute function. The CropWatch team provides the training course, covering the use of GVG tools, crop type classification, and validation. The technicians from IRIMHE and the CropWatch team jointly conducted the algorithm designing of crop type classification.

The main outcomes of the Capdev initiative

Technicians of the National Remote Sensing Center, Information and Research Institute of Meteorology, Hydrology, and Environment (IRIMHE) were trained to master the entire processing chain of crop type classification, including in-suit data collection, satellite image processing, training of machine learning classifier, crop type classification, and validation.

As a result, technicians from IRIMHE were able to use the GVG (GPS-Video-GIS) APP to collect geo-tagged crop type information after training. They also mastered the basic skill of Sentinel-1/2 data processing and machine learning algorithms for crop type classification.

An integrated Sentinel-1/2 data was designed by IRIMHE and the CropWatch team. The algorithm is realised in the Google Earth Engine (GEE) platform, and it is easy to deploy and migrate for the targeted region's crop type identification.

Another main outcome was the contribution of the up-to-date 10m crop-type maps for the development of crop monitoring and food security-related policy making.

Concrete activities and outputs

From the 6th-26th of September 2018, a total of 721 samples (Figure 23) were collected in Darkhan and Selenge by IRIMHE with the GVG tool, including 508 spring wheat samples, 76 rapeseed samples, and 137 fallow field samples. The exact distribution of spring wheat, rapeseed, and fallow land was generated and delivered to IRIMHE which provides crucial information for the estimation of spring wheat production. The work was summarised by technicians from IRIME and CropWatch team for a scientific paper and published in the Remote Sensing in 2022.

Another main output was the 10m crop-type maps (Figure 24) with an overall accuracy of 0.93 which filled in the gap of the high-resolution crop-type map in the provinces of Darkhan and Selenge in Mongolia.

Evaluation, reflection, and lessons learned

This CapDev initiative is an example of good practices in South-South and Triangular Cooperation for Sustainable Development—Give a man a fish and you feed him for a day; teach a man to fish and you feed him for a lifetime. Joint crop type mapping not only provides crop type data at the 10-meter spatial resolution but also provides a methodology on how to conduct crop types, which is critical for the sustainable management of agriculture.

The application of GVG tools provides a fast and effective way to collect in-suit data that is easy to install and use after a brief training. The use of the GEE platform for integrating strong computing resources and rich satellite information provides an easy way to access and analyse satellite data, creating a friendly interface to realise the algorithm.

Agricultural monitoring requires the support of field activities that need funding assistance. The outbreak of COVID-19 and the economic recession increase the difficulties of seeking funding and the organization of offline training. The limitation of computing and memory of GEE somehow limits the use of algorithms in the study area. Successful CapDev requires good expertise and skills support, as well as the systematic and structured organization of training sessions.

Now, the multi-annual and in-season crop type mapping is under planning in Mongolia's major crop-producing area which will provide significant support for food security assessment.

Opportunities for up-scaling or out-scaling

In the next step, we will expand the triangular Cooperation for Sustainable Development throughout all of Mongolia as well as several other developing countries with similar cropping systems. The crop classification tool's upgrade to an interactive interface will be beneficial for out-scaling.

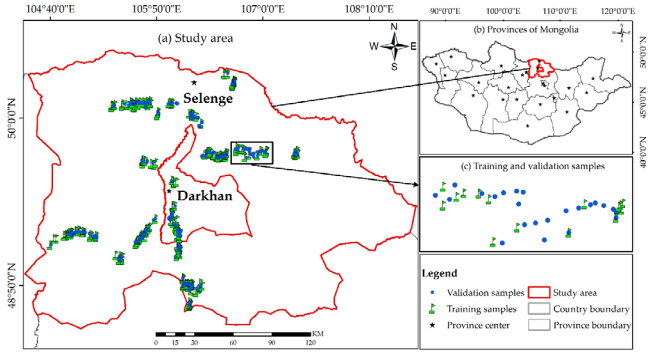

Figure 23 - In-situ data collection in Mongolia

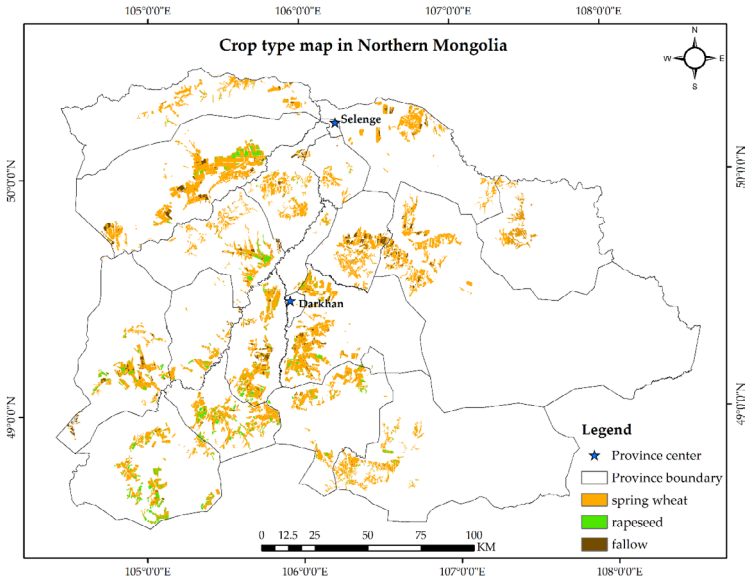

Figure 24 - Crop type distribution in the provinces of Darkhan and Selenge in Mongolia in 2018

12. EOSTAT – Ecuador: integrated use of EO data and process-based crop growth model (SALUS) for official crop statistics

Lorenzo De Simone, FAO; Bruno Basso, Michigan State University

Problem statement - justification of the Capdev initiative

Ecuador is suffering pronounced climate variability related to the El Niño Southern Oscillation (ENSO) which has led to increased rainfall and floods in the coast and Western Andes, and droughts in the Northern and Eastern areas. This has triggered the Ministerio de Agricultura y Ganaderia (MAG) to establish a sustainable national crop estimation system to ensure adequate food security decisions. The system needs to be accurate, and to be able to forecast crop yields as early as possible ahead of the harvest.

The (expected) impact of the Capdev initiative

Drought and floods have a negative impact on crop production, food affordability, and food security. Reliable and timely crop estimates are required to support decision-making that protects food security by balancing the amounts of grain imports and exports along with other food security measures. Through this initiative, MAG will be equipped with tools, methods, and knowhow to forecast maize and rice yield at the national level ahead of time through integrated use of EO data, geospatial data, and a process-based crop growth model, specifically the system approach for land use sustainability (SALUS) developed by Michigan State University.

The stakeholders involved and their roles

The main stakeholder is MAG. MAG's role has been fundamental in providing information on the current agricultural statistical system in place, sharing the national agricultural survey protocols, and in providing access to historical survey data including georeferenced crop area and crop cuts. MAG has also been fundamental in calibrating the crop growth model by advising on cultivars, crop calendars, and local agronomic practices. MAG has also shared geospatial data including crop parcels and the national soil map. The technical team at MAG, including the minister, has participated in a series of webinars and hands-on training, on the use of the CropMapper Tool developed by FAO and Michigan State University.

The main outcomes of the Capdev initiative

The project has co-created disaggregated crop yield data that allows for informed decision-making by MAG, enhancing its capacity to predict crop yields ahead of harvest. A full assessment of outcomes will require a few more years of project implementation and continued efforts.

Concrete activities and outputs

A national crop yield forecasting system has been developed that is scientifically robust, transparent, and trusted by MAG. The system is called EOSTAT and has an administrative interface, and a public user interface (Figure 25) accessible at: https://msu-cropmapper.users.earthengine.app/view/ecuador-end-user

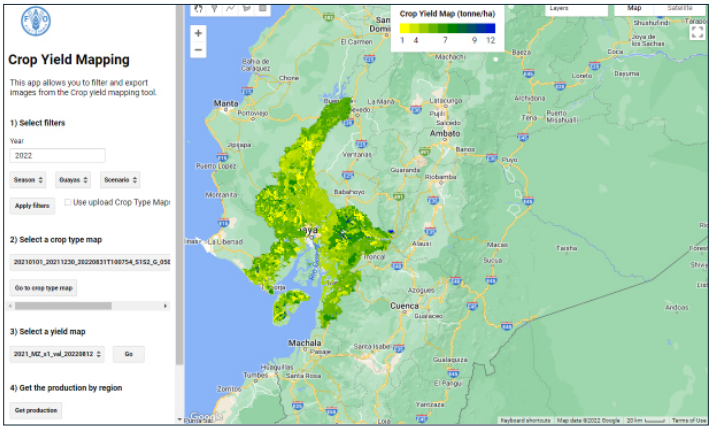

Figure 25 - The EOSTAT Interface

The SALUS model, appropriately calibrated using observed crop yields and using EO and geospatial inputs for soil and climate, was able to reproduce the observed yields of main commodities (Figure 26).

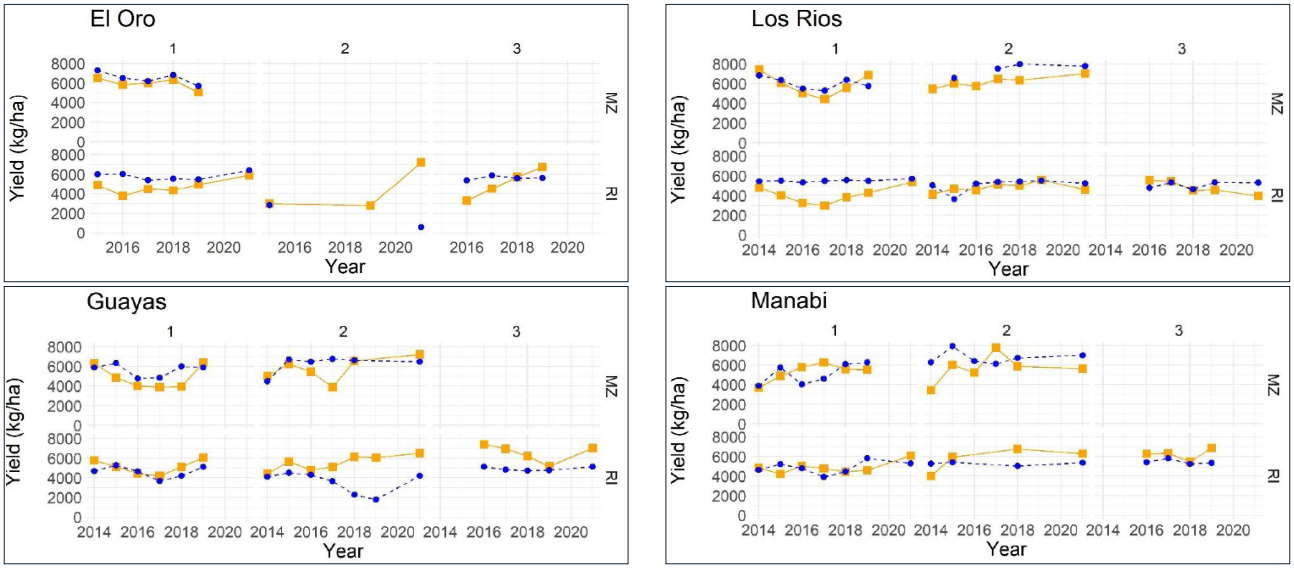

Figure 26 - Calibrated yield of maize (MZ) and rice (RI) by administrative district for each of the three growing seasons in Ecuador. Observed medians are shown in yellow and modeled yields are in blue. Maize is not grown in season 3.

Evaluation of errors in these estimates was limited due to both data scarcity and data variability. Continuous crop productivity simulations were compared to point crop data to produce spatial yield and error maps (Figure 27). Error calculations require large amounts of data, even accumulated across the calibration period there are regions with low data coverage.

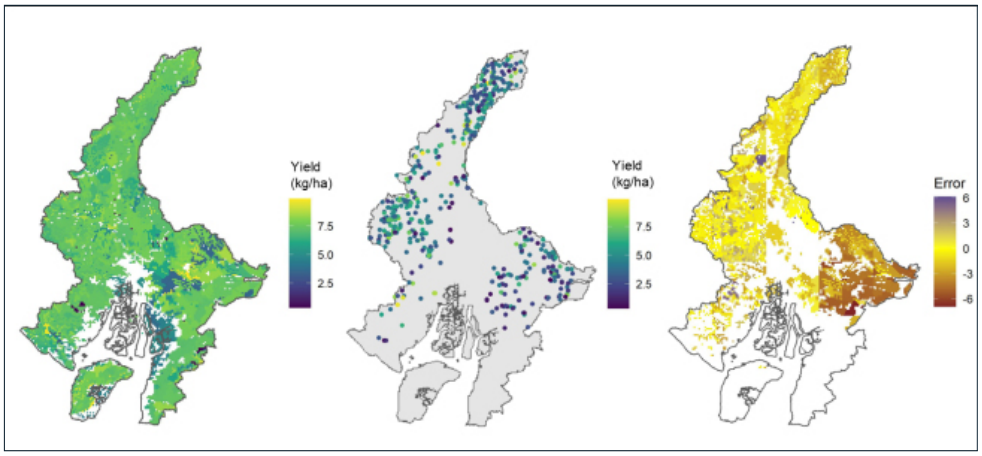

Figure 27 - This case study in Guayas shows (from left to right) average maize yields, observed yield points, and average error by zone. Regions with low sample density have high uncertainty in yield in space and time. Spatial clustering of errors suggest systemic variability in input data.

Evaluation, reflection, and lessons learned

The EOSTAT approach accurately determined historical and future yields in Ecuador including three climatic scenarios dry (seco), normal (Normal), and wet (humedo). The tool demonstrated the feasibility of crop yield modelling at a national scale using EO data as inputs to a crop growth model, running on GEE and on Kubernetes technology. The project was implemented in 2022 and has been running for over 12 months thus far. This was sufficient to co-create a prototype application, demonstrate the solution in collaboration with MAG, and deliver an initial round of training events. MAG has provided very positive feedback and expressed its commitment to continue using the EOSTAT solution. In this context, FAO is also committed to continuing the collaboration and has allocated funding for 2023.

Limitations of global earth observation datasets

While exceptionally powerful, the uniform application of Earth observation data and their derivative products to inform both crop mapping and crop modelling present location-dependent challenges.

1. Soil dataset coverage is not globally uniform except for a couple of machines learning extrapolated data sets. The presence of extreme values and in-country expert concerns indicate that in-country data, where available, is likely to be more highly trusted and may present less bias than simulated, gridded data. Soil texture and soil organic material both highly impact simulations of crop yield.

2. Coverage and duration of metrological and reanalysis data present a limitation and require the development of the best available data, from site to site.

3. Satellite coverage in the tropics (±23.5° latitude) presents a significant challenge in the form of perpetual cloud cover. This requires consideration of optical EO imagery with higher temporal resolution and/or the use of SAR data such as Sentinel-1.

Required in-country data

Training and testing of crop mapping and yield modelling will continue to require in-country data. The variability in ground truth values and uncertainty in modelled production is an opportunity for interactive assessments of the ground truth data collection and model improvements.

1. The ranges of crops monitored dictates the ability to effectively model and assess the variability of those crops.

2. The collection of field locations, crop management, and yield data may not always be co-located due to limited geo-referencing (i.e., crop survey points located at producers' homes or where cell phone signal was available) and approximation of field boundaries. Crop location and crop management in the case of Ecuador were collected by different departments. Additional hardware (i.e., GPS units) and technical training for enumerators is desirable.

3. The chain of data custody can be improved. Consistent methods for sample collection and laboratory analysis may reduce the variability in observed yield. In Ecuador, laboratories for analysing samples are selected based on proximity to the field sites. The use of many labs, perhaps using non-standardised methods, was identified by in-country experts as a source of potential variability.

4. Data cleaning is a constant challenge. Inconsistency in formatting and in units challenge the rapid adoption of this integrated tool (EOSTAT). A strict user interface may alleviate these problems but would also raise the entry bar. Initial setup and ongoing data cleaning in-country is required for the operation of this integrated tool.

5. The quality and spatial distribution of soil characteristics are likely to vary from country to country. Soil characteristics highly impact modelled crop productivity. The use of robust generic soils, with general properties and locations dictated by in-country data, may reduce extreme heterogeneity to regionally appropriate levels and avoid the negative impacts of outliers in soil variable values.

In-country spatial/temporal variability

The selection of the scale of analysis, both in space and time, presents critical challenges in balancing computational efficiency, sufficient granularity, and regionally useful information.

1. Farm-level simulation is infeasible given variability in global EO and local data. Productivity modelling is dependent on point-based soil and climate information and this information should capture the climatic and topographic regions of the country and their effects on crop yield. High-resolution simulations that are highly impacted by soil heterogeneity (real or data error) may reduce the usefulness of yield estimates at the regional and national scale.

2. Anomalies in soil and climate datasets may be present in yield estimations. With limited in-country data (i.e., ground truth meteorological data in Ecuador were not readily available) quantification and correction of these errors is challenging. Distinguishing real variability in yield due to soil, weather, and management differences from random and systemic error remains a large challenge. Quantification of variability over time and space through analysis of temporal and spatial coefficients of variation should inform future ground truth data collection.

3. Management may change over time and across regions. Limited information and history from ground truth data do not allow for the analysis of these trends and may introduce systematic bias in productivity estimates. Periodic calibration of best management may be needed to ensure technological advancements are captured.

4. The effects of climate change are also changing the yield response of crops independently from management. Beyond updating current climate inputs, the effects of extreme events outside of the historic record will introduce additional uncertainty. Addressing the probability of occurrence and the effect of such events is future work for the estimation of productivity and production.

Opportunities for up-scaling or out-scaling

The system can be operationalised at a district, provincial, and national scale in all regions/countries where agricultural production estimates are required, and where the minimum requirements for soil, climate, and crop management data are met for the initial calibration of the model, and for the validation for a reference baseline.

F: Capdev in GEOGLAM: next steps and stewardship of materials

1. Operational steps for Capdev in GEOGLAM

Socialise the guidance document

The GEOGLAM CapDev Team is well connected to regional GEOGLAM activities and efforts as well as to agencies that support and fund the EO-based research and development cycle for crop monitoring. Socialising the Guidance Document in these networks and agencies is an essential next step, so that it can become a reference document for CapDev practices, and funded initiatives adopt the tools, practices, and principles.

Make the tools and practices as accessible and widely known as possible

Whilst each case study has used one or more of the tools and models from Sections C and D, there is continuous need for GEOGLAM to evaluate its own internal capacity to ensure broad awareness and knowledge of all the tools and good practices that we have at our disposal. We will develop and host webinars on the tools and good practices from the Guidance Document. The number, type and expected outcomes of these webinars will be determined based on requests from the GEOGLAM community; they could be technical webinars, webinars on good practices for stakeholder engagement, or webinars about success stories for example. The webinars will be hosted on the same website as the Guidance Document. The target audience will be the CapDev Team and other CapDev practitioners within GEOGLAM. Our aim is that the material from the Document and webinars will, over time, be repurposed by the GEOGLAM community in a training of trainers approach resulting in regional webinars, preferably held in regionally relevant languages to reach as many local stakeholders as possible.

Capacity development for operational capacity to use EO

The case studies showcase various levels of capacity development from individual to organisational to institutional. GEOGLAM is geared towards operational capacity to use EO. There is a pipeline process of capacity development starting with training individuals to have the required skills for the EO workflows that support operational systems. Technical training like this will always have a key role. The emphasis for GEOGLAM should be on ensuring that operational crop monitoring systems can be developed and sustainably maintained to ensure continuity of EO-based crop monitoring services and products. This implies a focus on the organisational to institutional level of capacity development.

Coordination within the community: a way of working for the GEOGLAM CapDev team

It follows from the above point on operational capacity that we must scale up our impact to meet increasing demand so that national and regionally mandated organisations are enabled to host, maintain, and adapt their own crop monitoring systems and/or gain the required knowledge to generate EO-based datasets. Reaching this level is a challenge as is understanding why reaching it consistently has been successful or less successful in different settings. A key question that the CapDev Team needs to address is "how can we build on those lessons?" so that we can continue to support countries and mandated organisations sustainably and in a coordinated way to make the best use of the diverse resources and knowledge available amongst the community. Within GEOGLAM, and in the spirit of practicing what we preach, the CapDev Team will restructure itself and its way of working around a Strategic Pathway with the aim of supporting more effective food security-related policy and decisions via the GEOGLAM Community of Practice. Co-developing the Pathway will also ensure that lessons learned and success stories are incorporated along with the current collection of principles, practices, and tools to become a unified GEOGLAM voice on capacity development that focuses on communication and collaboration to maximise our societal impact.

Alignment of activities with implementation of national adaptation plans

The CapDev Guidance Document and the GEO Supplement to the UNFCCC NAP "Guidelines on Integrating Earth Observations into the Formulation and Implementation of National Adaptation Plans: Agriculture and Food Security" document share several common purposes such as identifying user needs through in-country consultation and engagement, and identifying the technical and institutional resources that countries need for the successful implementation of agriculture monitoring. The CapDev Guidance Document is already a part of the NAP strategy and we should further utilise the NAP process (the implementation steps) to better understand national CapDev needs and gaps for agricultural monitoring and how to address them.

2. Stewardship of CapDev materials

A dedicated home on the GEOGLAM website

This Guidance Document will be made available on the GEOGLAM website as a PDF document in English. Updates to the document will take place as and when other useful tools become recognised within the community as good practice and can be included in Section D.

Translation of the guidance document

We have the intention to translate the Document into several languages to facilitate further uptake with the global GEOGLAM community and beyond. Our first priorities are Chinese, French, Spanish, and Portuguese, and others may follow depending on demand. We recognise that we can centrally support the translation into some languages, but others will require voluntary community effort, and we will release translated versions as and when ready.

Encouraging more case studies

The first version of the Guidance Document contains 12 case studies. Whilst these are representative of the impact that the GEOGLAM community has achieved through various capacity development activities around the world, it is far from exhaustive; other stories of impact via capacity development also deserve to be shared. To facilitate this, each case study will be hosted as a separate short document on the same website and new case studies will be added to this archive over time.

Encouraging reuse

Together, the Document, the webinars, and the case studies will form an online resource for GEOGLAM and the wider (G)EO community. All these materials will be published under a Creative Commons licence (CC BY-NC 4.0), and we strongly encourage their reuse, adaptation, and inclusion in other capacity development toolkits in any suitable format; we only require that attribution is given to the authors.

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