

MOSIS - SATELLITE-MANAGED IRRIGATION WATER FEES - APPLICATION TO RICE PERIMETER IN SENEGAL

MOSIS - TARIFICATION DE L'EAU D'IRRIGATION GEREES PAR SATELLITE - APPLICATION SUR LE PERIMETRE RIZICOLE DU SENEGAL

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ABSTRACT

The Senegal River Valley is a major agricultural region where traditional agro-pastoral systems coexist with large-scale irrigated farming. Under increasing pressure from climate change, accurate assessment of irrigated areas and associated water consumption remains a critical challenge for sustainable water resource management and sustainable economic development. Rice cultivation alone accounts for approximately 85% of billed irrigation water, making its monitoring a strategic priority.

However, the situation is critical. In this vast rice-growing region, of strategic importance to both Senegal and Mauritania, estimating irrigated areas and associated water consumption is complex and fluctuates annually depending on hydro-climatic conditions. This implies technical challenges such as the ability to monitor water use, particularly irrigated rice cultivation. In this context, satellite imagery represents a relevant data source with global coverage and constantly improving spatio-temporal resolution, far less restrictive than field surveys for observing changes in the territory and thus able to support medium- and long-term water resource management decisions.

In this context, MOSIS project (Sharing Satellite Observations for Service Innovation) was launched in 2018. MOSIS (Monitoring System for Irrigated Surfaces) project is an operational decision-support system based on Sentinel-2 satellite imagery. Developed through a collaboration between SOGED SOGED (as a subsidiary of the OMVS (Organization for the Development of the Senegal River)) and Rives & Eaux du Sud-Ouest (formerly CACG - Compagnie d'aménagement des coteaux de Gascogne), the platform integrates remote sensing indicators—namely the Modified Normalized Difference Water Index (MNDWI) and the Normalized Difference Vegetation Index (NDVI)—to identify and quantify irrigated rice fields. MOSIS has been supported since the project's inception through decentralized cooperation by the French Adour-Garonne Water Agency (AEAG).

Thereby, MOSIS provides spatially explicit information through a WebGIS interface, enabling improved identification of users, better estimation of irrigated areas, and enhanced efficiency in water fee collection. Results demonstrate the potential of satellite-based solutions to strengthen water governance and support sustainable irrigation management in data-scarce environments.

Keywords: water consumption; satellite imagery; irrigated rice fields; satellite-based solutions; sustainable irrigation management.

RESUME

La vallée du fleuve Sénégal est une région agricole majeure où coexistent des systèmes agro-pastoraux traditionnels et une agriculture irriguée à grande échelle. Sous la pression croissante du changement climatique, l'évaluation précise des zones irriguées et de la consommation d'eau associée reste un défi crucial à relever pour une gestion durable des ressources en eau et un développement économique

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durable. La riziculture représente à elle seule environ 85% de l'eau d'irrigation facturée, ce qui fait de sa surveillance une priorité stratégique.

Cependant, la situation est critique. Dans cette vaste région de riziculture, d'importance stratégique tant pour le Sénégal que pour la Mauritanie, l'estimation des superficies irriguées et de la consommation d'eau associée est complexe et varie d'une année à l'autre en fonction des conditions hydro-climatiques. Cela implique des défis techniques tels que la capacité à surveiller l'utilisation de l'eau, en particulier la riziculture irriguée. Dans ce contexte, l'imagerie satellitaire constitue une source de données pertinente, offrant une couverture mondiale et une résolution spatio-temporelle en constante amélioration, bien moins restrictive que les enquêtes menées sur le terrain pour observer les évolutions du territoire et donc capable de soutenir les décisions de gestion des ressources en eau à moyen et long terme.

Dans ce contexte, le projet MOSIS (Sharing Satellite Observations for Service Innovation) a été lancé en 2018. Le projet MOSIS (Monitoring System for Irrigated Surfaces) est un système opérationnel d'aide à la décision basé sur l'imagerie satellitaire Sentinel-2. Développé grâce à une collaboration entre SOGED (filiale de l'OMVS- Organisation pour la mise en valeur du fleuve Sénégal) et Rives & Eaux du Sud-Ouest (anciennement CACG - Compagnie d'aménagement des coteaux de Gascogne), la plateforme intègre des indicateurs de télédétection — à savoir l'indice d'eau par différence normalisée modifiée (MNDWI) et l'indice de végétation par différence normalisée (NDVI) — afin d'identifier et de quantifier les rizières irriguées. Depuis sa création, le projet MOSIS est soutenu par la coopération décentralisée de l'Agence de l'eau Adour-Garonne (AEAG).

Ainsi, le MOSIS fournit des informations spatialement explicites via une interface WebGIS, permettant une meilleure identification des usagers, une meilleure estimation des zones irriguées et une efficacité accrue dans la collecte des redevances d'eau. Les résultats démontrent le potentiel des solutions satellitaires pour renforcer la gouvernance de l'eau et soutenir une gestion durable de l'irrigation dans des environnements où les données sont rares.

Mots-clés : Consommation d'eau; Imagerie satellitaire; Rizières irriguées; Solutions satellitaires; Gestion durable de l'irrigation.

MOSIS ADDED VALUE

Assessing water consumption for agricultural use is essential for managers to better anticipate the resource-need balance of the territory they manage. In this context, satellite imagery represents a relevant data source for evaluating irrigated areas and crop rotations to support medium- and long-term water resource management decisions. The objectives of this study are therefore to estimate irrigated crop areas and water requirements at the territorial level.

The tool is built around various open-source software components for processing satellite data (specifically, irrigated areas are detected using a water presence indicator (MNDWI) and then validated by the presence of crops (NDVI)), data management and display via a web-based platform accessible online and viewable from the field, mapping databases, and customer databases (irrigation water users who are liable for a service providing this water resource).

In practical terms, MOSIS platform allows SOGED to act based on spatially referenced information and indicators. Specifically, the assessment of irrigated areas using remote sensing enables the local manager in the river delta region to better identify users, evaluate the allocation of river water resources, and improve the collection rate of fees related to water use for rice cultivation.

The use of MOSIS has already demonstrated significant added value in the field: improved identification of users and land, increased revenue, enhanced communication with users, data certification, and more. 2026 should mark the end of the development program with the full operational deployment of MOSIS independently at the SOGED level. Further opportunities are anticipated in the coming years, particularly

using AI (Artificial Intelligence) to (i) achieve a higher level of automation for the tool, (ii) detect increasingly smaller cultivated areas, and (iii) expand the system to include other types of crops.



Figure 1. Screenshot of the MOSIS platform allowing identification of irrigated areas and then comparison of declared and irrigated areas.

MOSIS DEVELOPMENT

Area of the project

The Senegal River theoretically allows for the irrigation of approximately 248,000 hectares (SDAGE, 2009). The use of irrigation and environmental needs is estimated at around 4 billion cubic meters of water. During the rainy season (July–December) and the dry season (February–June), the main crop remains rice. However, during the cool dry season (December–February), the following food crops are cultivated: onions, tomatoes, okra, sweet potatoes, maize, sorghum, watermelon, and peanuts. To test the approach, the project focused on flood irrigation for rice cultivation in the river delta between Saint-Louis and Podor. This area accounts for 80% of the irrigated land in the valley (Fig. 1). Twenty-three rice-growing projects of over 200 hectares each have been pre-selected by SOGED for monitoring over the two rice-growing seasons (rainy season and dry season).

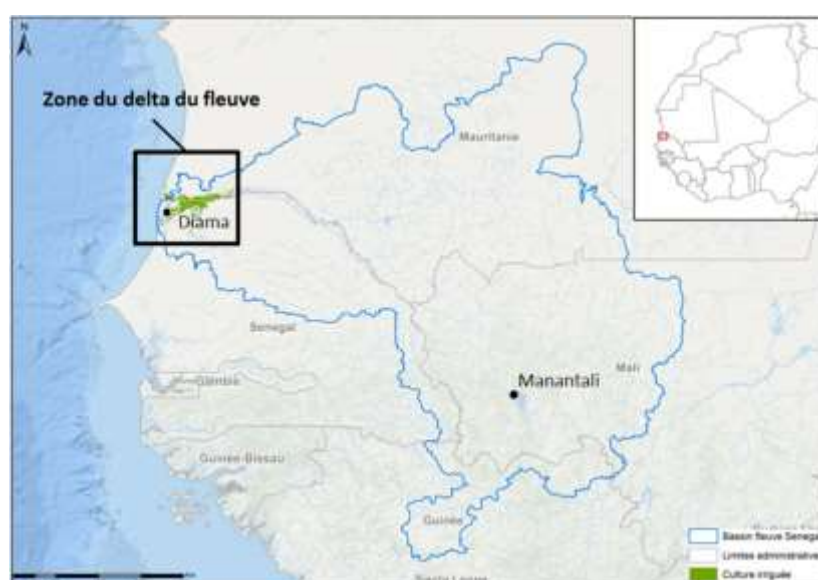


Figure 2. Area of MOSIS development.

Design service

A Living Lab and service design methodology was implemented throughout the project to focus on the needs and context of the end users (Bergvall-Kåreborn and Ståhlbröst, 2009; Dell'Era and Landoni, 2014). Creativity and co-design workshops were conducted to properly analyze needs and transform them into functional and technical requirements. An iterative specification/programming/delivery cycle approach was used to ensure the tool's alignment with end-user needs. The agile Scrum method was used for software development (Vlaanderen et al., 2011), adhering to agile values: regular interactions with the project team; operational readiness of the software; collaboration with the client; and adaptability to change.

Satellite image processing

Monitoring irrigated areas and crop development requires frequent revisits, such as those provided by Sentinel-2 imagery. Sentinel-2 is a constellation of two multispectral satellites (Sentinel-2A and Sentinel-2B) with high spatial resolution and high temporal repeatability (10-day revisits each, or 5 days when combining both satellites). It is developed by the European Space Agency (ESA) as part of the Copernicus Earth observation program, funded by the European Union. Sentinel-2 has a swath width of 290 km and a spatial resolution of 10 m, which is a good compromise for highlighting landscape details. Furthermore, for the various study areas, the continental surface data and services hub Theia (<http://theia.cnes.fr>) provides Sentinel-2 images pre-processed to remove atmospheric effects free of charge. Sentinel-2 images were therefore processed and analyzed over the past six years in the Senegal River delta area, every five days during the different rice growing seasons (hot off-season: March-July and rainy season: August-December). Image processing algorithms were developed using Python to automatically process the images and evaluate indicators of water presence (NDWI) and vegetation development (NDVI).

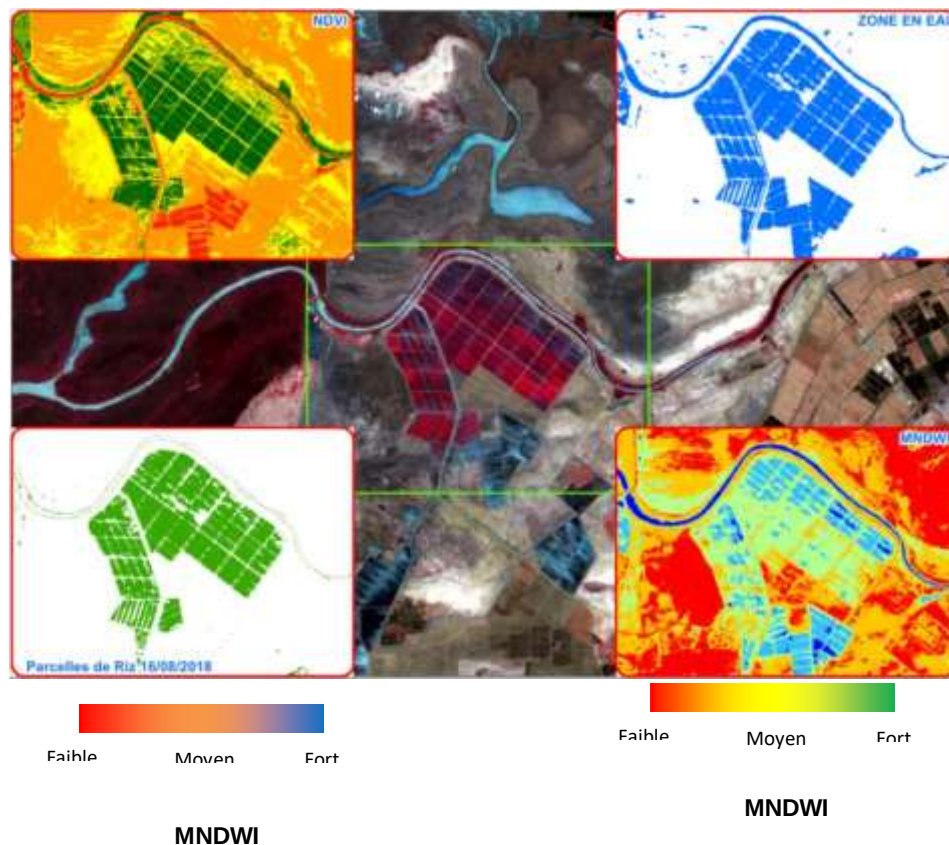


Figure 2. Examples of image processing on a management plan for the Senegal River watershed: NDVI indicator at the top left, MNDWI at the bottom right, remotely sensed areas "flooded" at the top right and remotely sensed areas in rice cultivation at the bottom left

WebGIS

A WebGIS application was implemented using open-source components to allow users to monitor remote sensing results in real time. The platform's system architecture consists of:

- a processing chain for evaluating irrigated areas using remote sensing and populating the database;
- a backend for handling client requests;
- a frontend for visualizing results;
- a database for storing historical data;
- a map server.

Field validation

At each stage of the process, during each rice production period, field validations were necessary. These allow for the training of satellite data processing algorithms and for the confirmation or refutation of existing mapping data.

Field validation is a key factor in its success. While technical support and methodological guidance were provided by experts from Rives & Eaux du Sud-Ouest, the majority of on-the-ground data collection, validation campaigns, and operational implementation were carried out by SOGED agents

Training and skills transfer

The development and operationalization of MOSIS was accompanied by a significant training and skills transfer program. This process was iterative, beginning at the project's launch and continuing to this day. At each stage, the resource people and topics were adjusted to meet the needs.

MOSIS IMPACTS & PERSPECTIVES

An operational tool – the 2.0 irrigation counter

An operational tool was therefore developed based on satellite image processing to locate and quantify irrigated rice fields. The main functionalities of the tool are: user authentication, standard map manipulation features, access to summary statistics on rice fields according to selected scales, monitoring of changes in irrigated areas by season, updating of data concerning landowners, and export of negotiation sheets or results in vector format. SOGED can thus track irrigation of plots and confirmation of rice growth via the platform. It can then compare the remotely detected areas with those declared and export a negotiation sheet with all the necessary information to send to clients or use as a basis for discussion.

User impacts

For SOGED, the tool optimizes the performance of agents involved in managing water rights with minimal additional human resources. It has, on a small scale for now, increased water rights revenue by expanding the billing base. In 2018, the number of billed users increased by 45% with the integration of 22 large users billed individually. Thanks to MOSIS, it is now possible to extend this approach to all large users. The combined effect of billing large agricultural users and raising the tariff level will result in a significant improvement in the collection rate for this category (nearly 33% of expected revenue over the 2020–2034 period). In the context of a complete overhaul of the legal, regulatory, and pricing structure of SOGED, this tool significantly improves SOGED's operational capabilities in managing the workload imposed by the application of the service regulations and the pricing schedule.

The history of users and cultivated areas allows for better control of actual land management on the ground and for assessing the financial impact of tariff changes on fees related to agricultural activities.

Qualitative impacts

The consortium had anticipated some resistance from users regarding the application of this tool for paying irrigation fees. Ultimately, the feedback from the field was surprising and positive. Users appreciated the fact that the field data was consistent for everyone, and this database facilitates dialogue between the various users and the agents involved in managing the fees. The tool also strengthens communication with state partners such as SONADER, SAED, ADRS, etc. These local partners expressed interest in using the tool and the potential associated services to be developed (monitoring agricultural yields, monitoring invasive plants, etc.). They requested geomatics training from SOGED to better carry out field missions to characterize the boundaries of irrigation systems and cultivated areas.

An example of decentralized cooperation serving an operational tool to support the sustainable management of water resource sharing The MOSIS project provides a concrete example of decentralized cooperation effectively supporting the development of an operational tool for sustainable water resource management. Initiated through a partnership between the Senegal River Basin authority (SOGED) and the French engineering organization Rives & Eaux du Sud-Ouest, and financially supported by the Adour-Garonne Water Agency, the project illustrates how international collaboration can facilitate technology transfer and capacity building. By combining local knowledge with technical expertise in satellite remote sensing, MOSIS enabled the co-design of a tool tailored to the specific needs of water managers in the Senegal River Valley. This cooperative framework ensured strong stakeholder engagement, promoting ownership and long-term sustainability. The resulting WebGIS platform enhances transparency in water allocation by providing objective, spatially explicit information on irrigated areas. It also improves equity in water fee collection by reducing discrepancies between declared and actual usage. Beyond its technical contribution, MOSIS strengthens institutional capacities and fosters dialogue among users, public agencies, and regional partners. As such, it demonstrates how decentralized cooperation can act as a catalyst for innovative, data-driven governance approaches in water-stressed agricultural systems.

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