OWASIS-NL

Observation of Water Availability - System of Integrated Services - Netherlands Case

Final Report

ARTES20 - Tender AO/1-7563/13/NL/EM

ESA - European Space Research and Technology

Centre – ESTEC

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P564

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Contents

1 Introduction

Water managers all over the world are confronted with increasing challenges related to climate change. The floods and periods of drought resulting from increasingly severe weather conditions cause worldwide economic damage, loss of nature, increased political and societal tensions and ultimately the loss of lives. The economically least viable countries are most vulnerable to the effects of climate change. Therefor it is not a surprise that the World Economic Forum declared the water crisis the #1 global risk based on impact to society (World Economic Forum, January 2015). To enhance the resilience of these vulnerable groups, all governments are increasingly challenged to manage water resources as effectively as possible.

Water managers have a wide range of (technological) measures at their disposal to prevent and mitigate the effects of floods and droughts. These measures range from technological solutions like improving the distribution network to governance related issues such as multilateral water treaties between partners in the same basin. With limited time and financial resources, it is crucial to facilitate the decision making process with proper, undisputed and timely information.

Currently, the lack of proper information on water availability is one of the most challenging obstacles for water management practices, especially in the less developed economies. In many cases data is **not available**, **incomplete** or it is **not accessible**. This leads to ineffective or erroneous decision making and can even cause additional water challenges. On the positive side, there is a huge potential to improve current water management practices by making detailed, complete and accurate data more easily available to water managers all over the world.

1.1 Objective of the OWASIS-NL feasibility study

The vision of the OWASIS-NL consortium is that the availability of adequate information is key to solving current and future challenges water managers throughout the world.

Therefore the consortium's main objective is to provide water managers with better information that supports them to prevent and mitigate the negative effects of floods and droughts and to monitor and manage their water system more effectively. To do so the consortium assessed the technical feasibility and commercial viability of a Water Availability Application service, which provides an essential component for improving monitoring, modelling, forecasting, and control of water availability, quality, soil subsidence and distribution for various user communities such as water management authorities, agro food industries, and multi-national industries.

1.2 ESA Integrated Applications Promotion (IAP)

The OWASIS-NL feasibility study was carried out within the European Space Agency's Integrated Applications Promotion (IAP) and resulted from the competitive tender AO/1-7563/13/NL/EM (ref: artes-apps.esa.int).

ESA's IAP programme, in close partnership with end-users, is dedicated to the development, implementation and pilot operations of Integrated Applications leading to sustainable services. The goal is to provide innovative added value to services by combining different space assets, such as Satellite Communications, Satellite Navigation, Earth Observation, Human Spaceflight technologies, and others, and by integrating them with existing terrestrial assets and technologies. The resulting services must exhibit technological feasibility, commercial viability and real benefits for the target users to guarantee their sustainability in the long term.

1.3 Study Team

The study was carried out by a consortium with leading internationally operating consulting companies and data and services providers:

- HydroLogic (Lead), NL; a hydroinformatics company for hydrological modelling, ICT tools development and service provider of HydroNET, which is available to the project. (www.hydrologic.nl)
- Arcadis, NL; biggest international consultant of the Netherlands with offices all over the world; also specialised in water management, ecology and water quality. Arcadis makes its enormous international industrial network available to the project. (www.arcadis.com)
- Alterra, NL; agriculture, water management, agri-food and soils experts and researchers, formally responsible for change detection of elevations and subsidence in the Netherlands. (www.alterra.nl)
- WaterWatch; owner of eLEAF; leading provider of high quality processed satellite data, operating world-wide, in particular using optical satellite based sensors. (www.eleaf.com)
- Starlab Ltd, UK; space-asset experts and service providers, originally from Barcelona, now operating also in UK, specialised in radar-based remote sensing. (http://www.starlab.es/)

1.4 Study Logic

The OWASIS-NL feasibility study was carried according to the generic structure recommended by ESA (see Fig. 1)

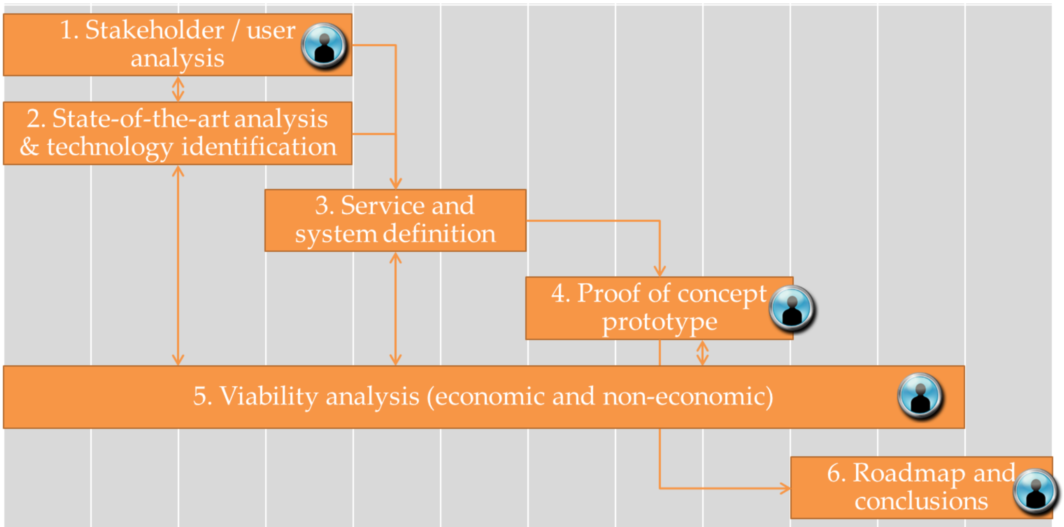

Fig. 1 Study Logic of the OWAIS-NL study

2 OWASIS-NL feasibility study

In 2014 and 2015, the OWASIS-NL consortium investigated the potential benefits of using space assets for improved water availability monitoring. A wide range of water managers from public water management authorities, industries and agriculture were involved to identify the most urgent user needs related to water availability information. Based on their needs, services were identified that add value to the conventional non-space based monitoring techniques.

Table 2-1 Involved Users and their interest in improved water availability information

		
Water Management Authorities are responsible for the water distribution within a river basin or catchment area. They can benefit from the availability of improved information on rainfall, soil moisture, groundwater, surface water and evapotranspiration. Improved water availability information can make operational and strategical processes more cost effective and transparent.	Because increasing pressure is being placed on water resources by industry and urban areas, water scarcity is increasing and agriculture is facing the challenge of producing more food for the world's growing population with reduced water resources. As such, improved water availability information is of main interest for the agro-food sector since it can help them to improve their processes and production efficiency.	Industries need (fresh) water as in-put in their production pro-cesses, as cooling water, process water or for energy production using hydro dams. For these purposes industries withdraw water from both surface and groundwater. Furthermore, many industrial production plants are vulnerable to floods. Improved information on the available water resources can help industries to make better risk assessments and to do a better production planning.

2.1 High level user needs and the added value of space assets

The OWASIS-NL feasibility study shows that all water managers are dealing with the distribution of a limited amount of water in space and time. In other words, they need to make sure that the right amount of water is available at the right place and at the right time. If too much water is available there is the risk of flooding. If too little water is available, there is a risk of drought. To efficiently manage the distribution of water, information is needed on the key hydrological parameters including precipitation, evaporation, inflow and outflow from ground and surface water and the amount of water stored in the soil and surface water.

Information on water distribution can be obtained from a number of resources like observations from the crowd, gauges, in situ-sensors, remote sensing and models. The last couple of decades also the opportunities to monitor water availability from space have become more and more promising. With the launch of new satellites more data becomes available that could benefit water managers.

This study integrated to two types of assets: earth observation and navigation. Earth observation uses satellite imagery to obtain precipitation forecasts, soil moisture contents and evapotranspiration data. GNSS technology is used to obtain the location of the user to provide local data on his mobile phone or tablet and for geotagging of in-situ measurements required for validation and calibration.

The feasibility study showed that space assets can be especially beneficial to obtain data on precipitation, evapotranspiration and soil moisture. For these parameters space assets provide the following benefits:

1. Space assets can obtain data from remote and poorly monitored areas;
2. Space assets can obtain data for large areas in a spatial resolution that would be much too costly to obtain through in situ measurements;
3. Space assets can obtain information at a regular interval, thus creating the possibility to effectively monitor the water availability over time.

4 Space assets do not have boarders, this makes it possible to provide trans-boundary water availability services.

2.2 OWASIS-NL services for improved water availability data

As part of the OWASIS-NL feasibility study multiple services were designed that provide water managers with valuable information based on data from space assets. These services were evaluated regarding their technical feasibility, operational availability and reliability, and economic viability.

2.2.1 Soil Water Storage Capacity Monitoring and Forecasting

Service that provides the user with historic, current and forecasted information on the soil water storage capacity. With this service the end user will quickly get an overview that shows where storage capacity is still available. Based on this information he can reduce the risk of drought and flooding and take better decisions on the distribution of water.

Fig. 2 Soil water storage application displaying the soil storage capacity as an average in mm per area

2.2.2 Agricultural Water Demand Monitoring and Forecasting

This service provides the end user with an overview that shows the water use from irrigation and compares this to the water allocation. Based on this information the user can monitor water use by irrigation in large areas and can take measures to prevent excessive water use by farmers.

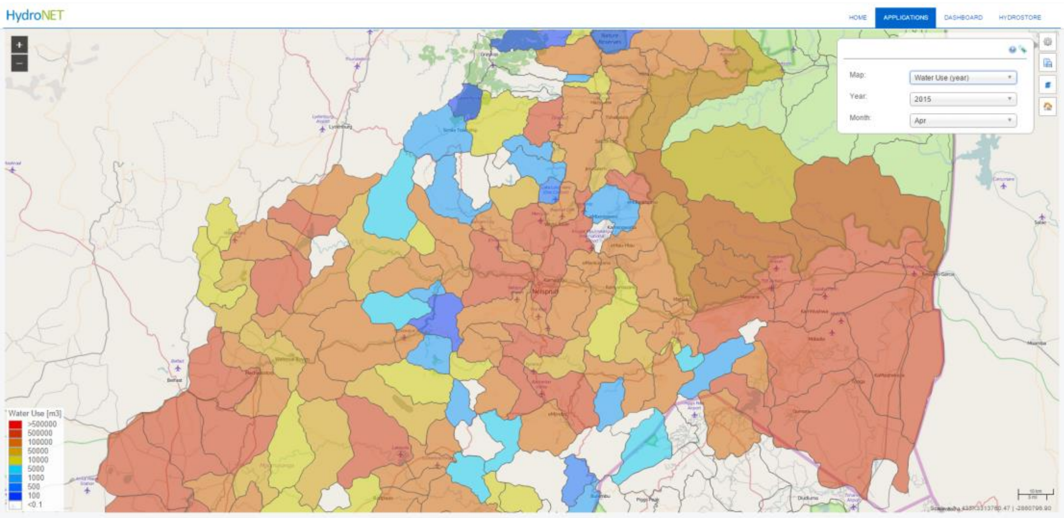

Fig. 3 Mock-up of the agricultural water demand service showing the water use per administrative area.

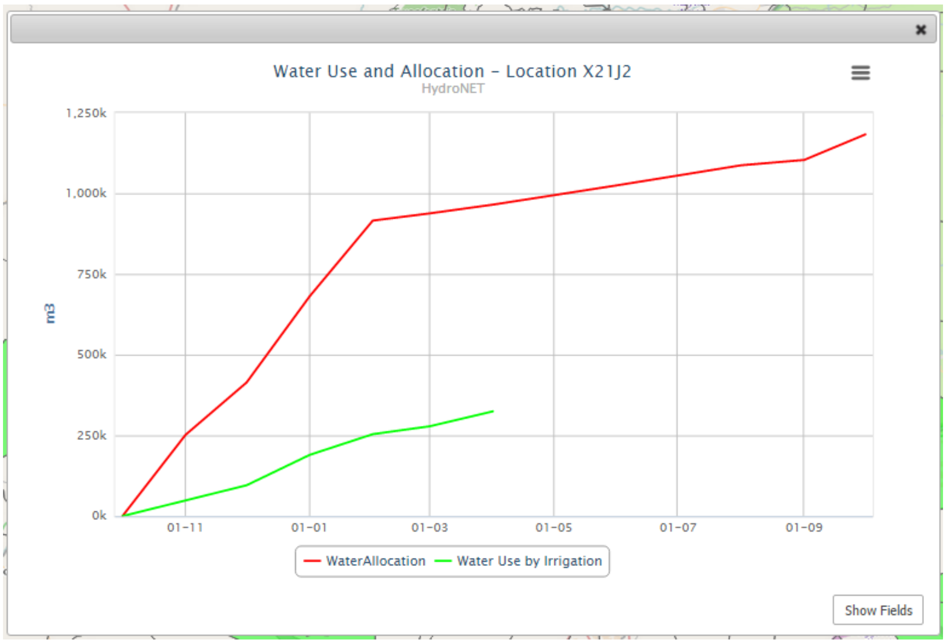

Fig. 4 The water demands service showing a graph summarizing the water use and allocation for all the fields in the area.

2.2.3 Water Inflow into Reservoirs

The Water Inflow service delivers value to customers by increasing the knowledge on how much water flows and will flow into the reservoir in the coming 10 days. This helps the reservoir manager to optimize the production of hydropower. Preventing spilling of reservoir water helps to realize the highest hydropower output.

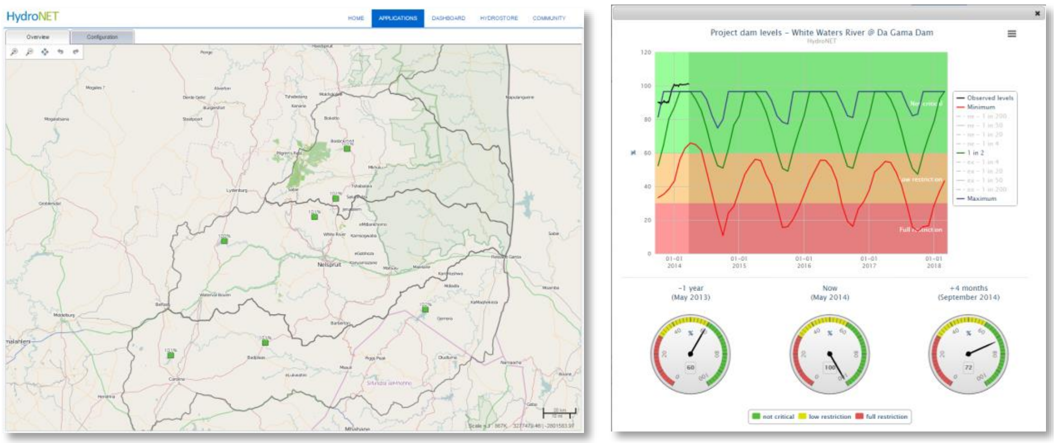

Fig. 5 Mock-up of the Water Inflow Forecast Service showing the current and expected dam levels

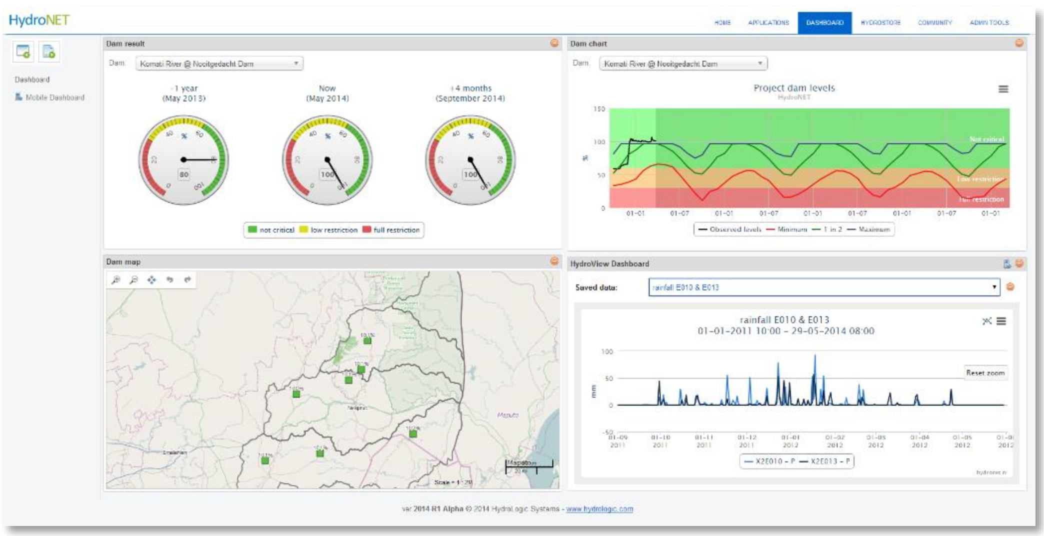

Fig. 6 Mock-up of a personalized control room dashboard for dam managers.

2.2.4 Flood Risk Mapping for Industrial Sites

With the flood risk mapping service for industries users will get access to flood warning forecast for their industrial sites based on weather predictions. Based on this information the user can take precautionary measures such as a temporary stop of production or a reallocation of its production to another area. This will reduce the direct and indirect damage related to flooding and the user will be able to optimize its production processes prior to a flood event.

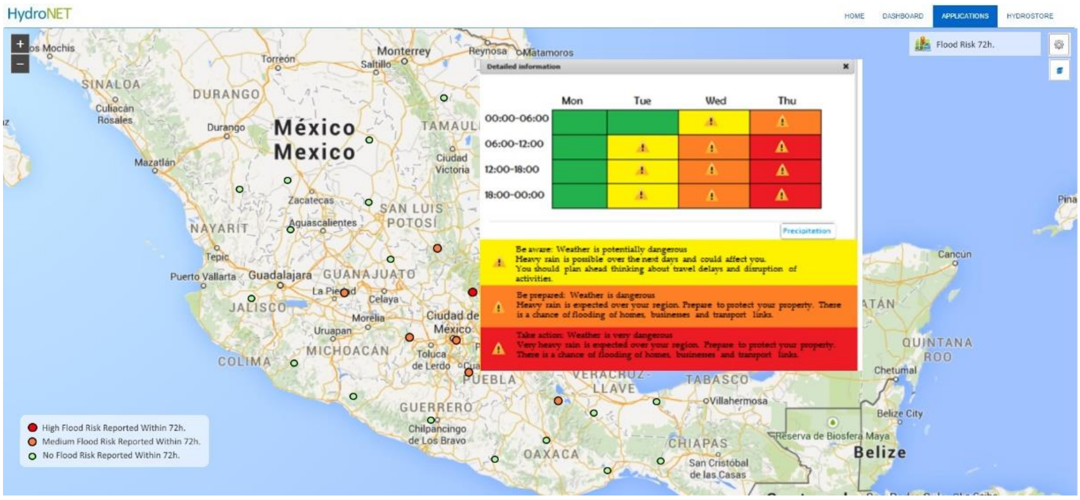

Fig. 7 Mock-up of flood risk map service

3 Evaluation of technical feasibility, economic and non-economic viability

During the feasibility study, four services were defined which provide a solution for improved information on water availability. As part of the study, these services were evaluated regarding their technical feasibility, economic and non-economic viability.

To assess the final viability of the services and to decide which services will be most suitable for further development into sustainable operational services we have performed a multi criteria analysis (MCA). In this analysis we assessed all the services on seven criteria which are important to ensure a successful follow up and market entry. The services with the highest total score are most likely to be successful and have been selected for further implementation.

Based on the results of the MCA (see Table 3-1) we can conclude that the 'soil water service' and the 'water auditing service' are the most feasible. These services are technically feasible and economically viable, clearly benefit from the use of space assets and there is a clear interest from the potential end users to participate in and invest in the further development and operation of the service.

The 'water inflow service' and 'flood risk service' showed to be less viable. The main reason for this is the lack of interest from end users to pay for the services. Furthermore, there is a limited added value of space assets since the services mainly require in-situ measurements. Finally, these services do not optimally match the product portfolio of the consortium members.

Table 3-1 Overall Feasibility of the OWASIS-NL services (see table 3-2 for a full explanation of the criteria and scoring methodology.

Service		1 Technical Viability	2 Economic Viability	3 Non-Economic Viability	4 Added Value of Space Assets	5 Risks associated to implementation	6 Willingness to participate	7 Place in Product portfolio	Overall Score
1	Soil Water Service	5	5	5	5	5	5	5	35
2	Water Auditing Service	5	5	5	5	5	3	5	32
3	Water Inflow Service	5	3	3	3	3	1	3	21
4	Flood Risk Service	5	3	3	3	3	1	3	21

Table 3-2 Criteria and Scoring methodology for Multi Criteria Analysis

Criteria	Scoring
1 **Technical** *Evaluates the technical feasibility*	1= the service is not technically feasible 3= the service is technically feasible but requires the development of new technologies. 5= the service is technically feasible and can be developed by combining existing and proven technologies.
2 **Economic** *Evaluates if the service can generate enough income to be sustainable.*	1= the service is not economically viable, pay back period takes too long. 3= the service is economically viable, pay back period is less than 3 years. 5= the service is economically viable, pay back period is less than two years with ESA contribution.
3 **Non-economic** *Evaluates if there are there any non-economic constraints that are limiting the successful implementation of the service.*	1= there are major non-economic constraints, no mitigation measures are available. 3= there are major non-economic constraints, mitigation measures are available. 4= there are minor non-economic constraints, mitigation measures are available 5= there are no non-economic constraints.
4 **Use of Space Assets** *Evaluates weather the use of space assets has added value in addition to the use of earth based technology.*	1= space assets are not required for the further development of the service and have no added value in addition to the use of earth based technology. 3= space assets are a valuable contribution to the development of the service and provide added value in addition to the use of earth based technology. 5= space are crucial for the development of the service. Without the use of space assets the service cannot be developed or is not economically viable.
5 **Risks** *What are the risks associated with the implementation of the solution?*	1= high risk associated with the implementation of the solution, no mitigation measures are available. 3= medium risk associated with the implementation of the service, mitigation measures are available. 5= low risk
6 **End user willingness to participate and pay** *Evaluates the willingness of the end user to participate and/or pay for the further development of the service and his willingness to pay for the operational service.*	1= end user is not willing to participate or pay 3= end user is willing to participate in the further development of the service and is willing to contribute in kind 5= end user is willing to participate in and pay for the further development of the service and is willing to pay for the operational service.
7 **Place in product portfolio:** *To what extend does the service fit in the current product portfolio of the consortium members involved.*	1= The service is outside of scope of the consortium members and is provided to a new customer or market. 3= The service is outside the current scope of work of the consortium members but the service is provided to an existing customer or market. Or the service is within the scope of the consortium member but is provided to a new customer or market. 5= The service fits well within the current scope of the consortium members and the service is provided to an existing customer or market.

4 Lessons Learned

After completion, the feasibility study was evaluated by the consortium members and the following lessons were drawn.

- **Added value of space assets for water managers**: the OWASIS-NL feasibility study showed that there is a clear added value of space assets for water managers. Especially for the monitoring of evapotranspiration and soil water content, earth observation images provide valuable water balance data compared to earth based technologies. Earth observation images are also a valuable source for precipitation data in areas where no radar or gauging networks are available. As was shown during the study, space assets are less suitable for monitoring surface water levels at high resolutions.

- **Focus**: for the success of the demonstration project it is important to focus on one or two clearly defined services. The broad design of the feasibility study resulted in unexpected delays because much time was needed to collect the required information from multiple user groups and to coordinate the results between the consortium partners. It is recommended to downselect services early in the activity, e.g. at the first review meeting.

- **User interest to participate in follow up**: it turned out that for two of the four services, the users were not interested to participate in and or provide funding for a demonstration project. Also, at this stage they were not willing to provide insight in their willingness to pay for a fully operational service. Unfortunately, this was discovered during the proof of concept phase of the study only. We therefore recommend to ask for commitment to through an in kind or cash contribution prior to the start of the study. As we experienced, especially customers from the industry and the energy sector had no interest to pay for services that are not fully developed and tested in an operational environment.

5 Roadmap for towards a demonstration project

During the OWASIS-NL feasibility study the technical feasibility and non-technical viability of four types of water availability services have been investigated for water management authorities, agro food industries and multi-national industries. The final feasibility assessment of this study resulted in two services that were recommended to be developed further in an ESA demonstration project. These applications help water managers to get the right information in the right time to the right person to support the right water management decisions. The following paragraphs describe the user challenges and user needs that will be addressed as well as a preliminary design of the services. The demonstration phase of the OWASIS-NL demonstration study is expected to start in the 2nd half of 2016.

5.1 Soil Water Storage capacity monitoring

With 29% of the Netherlands below sea level and 26% of the country prone to floods from rivers, efficient water management is crucial to keep the Dutch feet dry. And while fresh water is abundantly available for most of the time, drought, and more specifically the availability of fresh water, becomes an increasing problem due to the effects of climate change, e.g. rising sea levels.

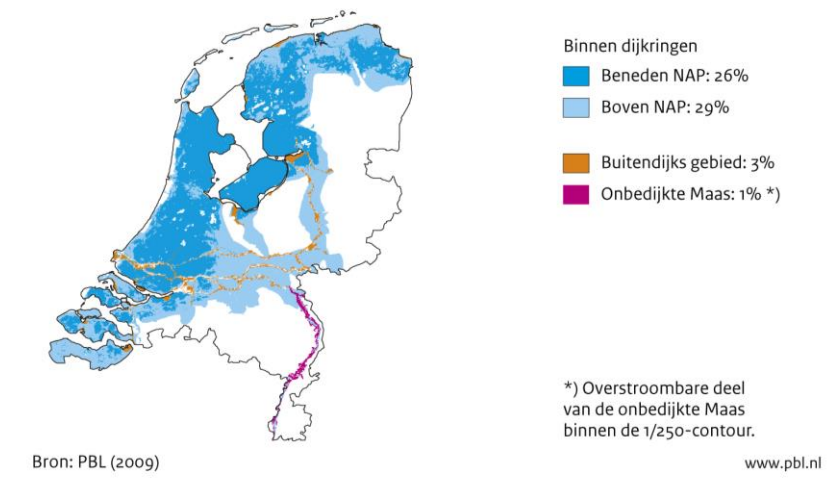

Fig. 8 Flood Risk in the Netherlands (source: www.pbl.nl)

The responsibility for management of the Dutch water systems is divided between the National Water Management Authority (Rijkswaterstaat) and the Regional Water Management Authorities (also called waterschappen). The National Water Authority is part of the Ministry of Infrastructure and the Environment and controls the coastal zone with its estuaries and the major rivers like Rhine and Meuse. These water systems are called the main water system. The other water systems are managed by 23 Regional Water Management Authorities.

In the OWASIS-NL feasibility study, representatives from Dutch Water Boards indicated the lack of reliable information on water availability and especially the water storage capacity as the most challenging problem in current water management, as this hydrological variable determines bot the risk of flooding during wet periods, and the need for irrigation in dry periods.

In the current operational process, the water manager has to estimate the soil storage capacity from groundwater levels and surface water levels. This way, it is virtually impossible to obtain a reliable estimation, because the soil storage capacity also depends on the actual evaporation, local soil conditions and the preceding weather conditions. The available (aggregated) information needs interpretation by the decision maker, which requires in-depth hydrological knowledge and increases the risk of wrong decisions, leading to unnecessary measures, damage and costs that could have been prevented by timely action based on the right information.

The soil water storage capacity service provides water managers with historic, current and forecasted information on the soil water storage capacity. This information is provided through a web based application that displays the information in interactive maps and graphs. This way water managers have access to more accurate information on a spatial scale that suits their needs. With this information water managers can more effectively distribute the available fresh water, anticipate upcoming events and thus reduce the risk of drought and flooding.

The OWASIS-NL feasibility study showed that space assets have the potential to greatly improve the estimations on the soil storage capacity. Especially the use of high resolution satellite based evapotranspiration data can have a great impact on the quality and availability of the soil water storage capacity information. The study showed that this data can smartly be combined with data from rain gauges, radars, numeric weather perdition models and ground water models.

Although the exact (economic) benefit of the soil storage capacity service is hard to estimate, we have identified the following gains:

- Efficient and improved allocation of water management resources: water management authorities have only limited water management resources (like pumping capacity) available. If water management authorities are able to identify where application of resources is most needed, capacity can be applied more efficiently.
- Reduced Flood risk: the potential damage of a flood in the Netherlands is enormous. Based on the location in the Netherlands, maximal economic damage of flooding is estimated between 300 million euros and 300 billion euros. Reducing the risk of a flood can save a huge amount of money.
- Standardization of water storage capacity estimates: as explained earlier soil water storage capacity is currently estimated based on the available data sources. Since every decision maker interprets the available data differently the outcomes of this process can be subjective and hard to compare because different methodologies are used. Introducing a standardized service for the whole of the Netherlands enables a more objective comparison of the soil storage capacity in time and space. This makes water management more safe and efficient.

The soil water storage capacity monitoring service provides the user with insight in the current and forecasted storage capacity of the soil. The objective of the demonstration project is to demonstrate an operational service for the Dutch Water Boards.

The service will be developed using the HydroNET platform. This platform is already used for strategical and operational water management purposes by all Dutch Water boards. To demonstrate the Soil Water Storage service we will connect multiple data sources which will be used in the Soil Water Storage algorithms (Fig. 9).

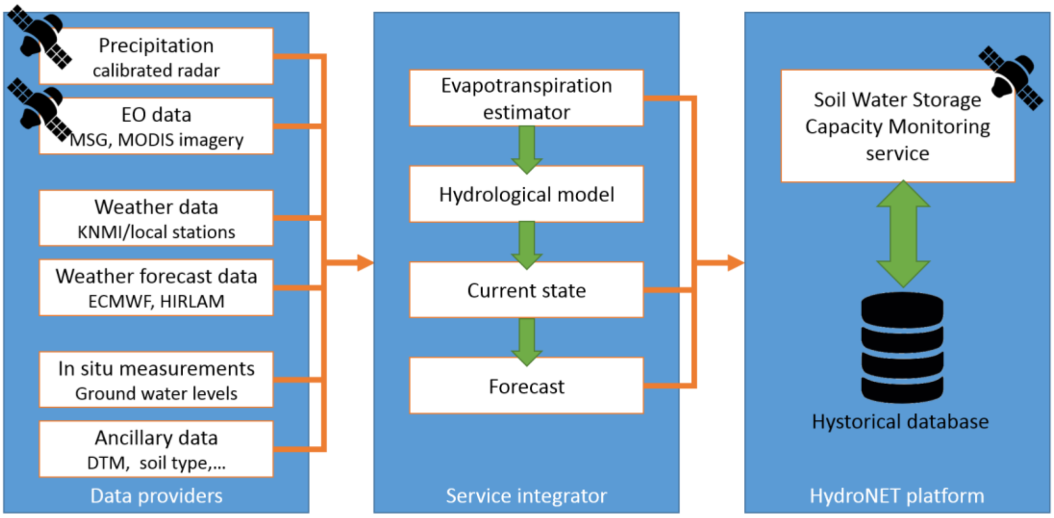

Fig. 9 System Architecture for the soil water storage capacity monitoring service

The service and the algorithms used are physics based and generic and can therefore be applied on any spatial and temporal scale. For very small scales, there are limitations in data availability and quality. On the other side of the spectrum, the user requirements state minimum temporal and spatial resolutions. As part of the design process, we will determine, in conjunction with the users, the optimal resolutions in terms of data availability and information density.

5.2 Water Auditing

South Africa is facing a severe water shortage. The expectation is that water demand will exceed water supply between 2025 and 2030. With the present high level of water resource utilization, water use efficiency must be substantially improved. Irrigation is currently by far the biggest water use in South Africa. In 2000, irrigation extracted 63% of the country's available surface water. Also the use of ground water is already exceeding the naturally available resources in most of the country. Currently lack of water availability is the most important factor that limits agricultural production. This situation is likely to worsen due to rapidly increasing demand from other sectors and climate change.

To regulate the amount of water being used for irrigation, South Africa introduced a water licensing mechanism in the National Water Act (NWA). This mechanism ensures equal distribution and efficient use of the available water resources. Under the licensing system, the water use for individual farmers and fields is registered in the WARM database.

Auditing on compliance of water allocation is currently a major challenge for water managers in South Africa. Irrigated fields are spread over a vast area and the number of fields to audit is enormous. For example, the Inkomati Usuthu Catchment Management Agency in the North East of South Africa alone needs to monitor over 50.000 farmers spread over an area roughly twice the size of the Netherlands. This makes it virtually impossible to monitor the water use by farmers in a conventional way, leading to non-compliance and unequal use of water resources.

The Water Auditing service provides water managers like the IUCMA with a monitoring tool that greatly enhances the effectiveness of the agency. The service uses evapotranspiration data form satellites and rainfall data from rain gauges and radar to calculate water use. The application compares the actual water use to the water allocation stated in the permits.

The OWASIS-NL feasibility study showed that the use of space assets in the water auditing application has the following gains:

- The use of space assets allows water managers to monitor the water use in large areas. This enables them to identify problem areas and to implement measures only in the areas where they are needed the most. This will lead to more efficient application of water management measures.
- The water auditing application makes it possible to monitor the water use for all fields and at a regular interval. Currently, regular water auditing is not possible because it is much too costly to monitor all fields at a regular interval.
- Because water use data is available on field level at a regular interval the service can be used to raise awareness showing farmers their water use compared to other farmers. This will increase their ability to use water more efficiently and to increase their crop output. The goal is to create more crop per drop.
- The water auditing allows to look over boarders. This allows to monitor water use in the entire Inkomati Catchment.

The water auditing service provides information on the water use by irrigation and compares this to the amount of water that is allocated to a specific area or field. Based on this information Water Management Authorities can monitor the water use in large areas and implement regulatory measures to save water and improve water allocation.

The water auditing service for the water authorities will provide the user maps and graphs displaying the water use per pixel, administrative area or field and compares this to the allocated amount of water (see Fig. 3 and Fig. 4). The colour in the area indicates the ratio of cumulative water use compared to the cumulative allocation. When the user clicks on one of the area's on the map a graph will appear showing the water use and water demand/allocation over time. This graphs shows the cumulative water use and the water demand / allocation from the beginning of the growing season.