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GRAPELOOK: SPACE BASED SERVICES TO IMPROVE WATER USE EFFICIENCY OF VINEYARDS IN SOUTH AFRICA

Annemarie Klaasse
WaterWatch BV, the Netherlands, a.klaasse@waterwatch.nl

Caren Jarmain
University of KwaZulu-Natal, South Africa, jarmainc@ukzn.ac.za

Andre Roux
Department of Agriculture: Western Cape, South Africa, andrer@elsenburg.com

Olivier Becu
European Space Agency, the Netherlands, olivier.becu@esa.int

Amnon Ginati
European Space Agency, the Netherlands, amnon.ginati@esa.int

Limited water resource availability and efficient water management are major global challenges facing policymakers in many countries of the world including South Africa. The GrapeLook project aims to address these topical issues through a pre-operational service that provides information on crop water, growth and nitrogen status of vineyards in Western Cape Province using satellite data. The demonstration carried out under the GrapeLook project validated the service and provided users with a deeper insight into the temporal and spatial processes in vineyards to improve water use efficiency.

The pre-operational GrapeLook service was provided via the website www.GrapeLook.co.za which made available free of charge weekly updates on crop parameters for the grape season of 2010-11. The success of the service was determined through the reliability of the service (on time, regular), the quality of the service (trust), the publicity of the service (awareness), the website usability (user friendliness), the website accessibility (website speed), the understanding of information (definition of concepts), and the usability of information (translation into farm practices).

During the project it was identified that the users of GrapeLook, grape farmers in Western Cape, are open and willing to adapt new technologies such as GrapeLook subject to validation that the benefits are worthwhile. To build trust and awareness within the farmer's community, the GrapeLook pre-operational service is envisaged to be sustained by institutional funds during the coming season 2011-2012. The medium term plan is to move by 2014 to a commercial service in which farmers, farmers advisors and water user associations will have to cover the costs accordingly.

INTRODUCTION

Availability of water resources and good water management practices are well acknowledged global challenges for the years to come. These issues are particularly acute in dry countries. In South Africa, water is a critical resource and there is strong competition between the urban, industrial and agriculture sectors. The National Water Act (1998)[1] states that water should be used efficiently and has to be reserved for basic human needs and for protecting aquatic eco-systems first, with agriculture having a lesser priority. However, agriculture remains of high economic importance as it contributes to export, employment and livelihood. The challenge is to increase agricultural production while reducing water consumption.

One of the major sectors in the Western Cape Province of South Africa is the table and wine grape industry. Water productivity or water use efficiency, defined as crop production divided by the total water consumption, is a vital parameter to assess agricultural performance (Bastiaanssen et all, 1999)[2].To optimise the water use efficiency, one needs information on the crop production and the crop water consumption. The physical process behind crop water consumption is the process of actual evapotranspiration (ET_{act}).

Information on crop water consumption is difficult to obtain. In situ measurements do not show the spatial variation and are expensive. Sophisticated remote sensing algorithms based on satellite data have been applied to provide field level data on evapotranspiration and water use efficiency worldwide.

The GrapeLook Project

WaterWatch, a Dutch firm, assessed the application of remote sensing data to optimize irrigation management of vineyards in the Western Cape Province from 2004-07 (Klaasse et al., 2008)[3]. Farmers were very interested in the results, but the retrospective nature of this study, in which the results only became available after the season ended, however limited the practical application of the data on farm level.

As a result, the Western Cape Provincial Department of Agriculture (supported by the Department of Agriculture, Forestry and Fisheries, the Dutch Embassy and the Integrated Applications Promotion programme of the European Space Agency) initiated the pre-operational service demonstration GrapeLook which was executed by WaterWatch in collaboration with the University of KwaZulu-Natal (UKZN) for the season 2010-11 (Klaasse et al, 2011)[4].

Goals and objectives

The project's goal was the development, integration, validation and pre-operational demonstration of a sustainable end-to-end service to optimize the utilization of water and fertilizers in South-African vineyards. Free online (web-based) access to information relating to crop water, growth and nitrogen status was made available using satellite data. The service provided weekly updates for the period 1 September 2010 to 30 April 2011 for all major (table and wine) grape producing areas of the Western Cape.

The objectives were to:

- Provide weekly updated semi-real time information on parameters such as crop growth, evapotranspiration deficits and crop nitrogen status for individual blocks/plots and farms using satellite technology;
- Forecast soil moisture change over the five days after satellite image acquisition (for participating farmers only);
- Disseminate this information through a website (www.GrapeLook.co.za) accessible to all (farmers, irrigation consultants, etc.); and
- Enable farmers, water use associations, South African authorities and other users to evaluate the benefits of the operational service as a tool to optimize water use and fertilizer application.

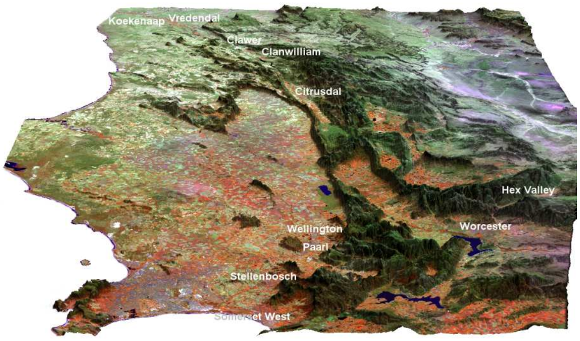

Figure 1: Overview of study areas

DESCRIPTION OF THE PRE-OPERATIONAL SERVICE

The GrapeLook system builds on existing terrestrial elements and space based tools and data which are integrated into one end-to-end service directly applicable to vineyards in the Western Cape Province in South Africa. The core of the system is the data processing framework which is fed with earth observation and in situ data, and creates the outputs that are disseminated to the user through a dedicated website and a Short Message Service (SMS).

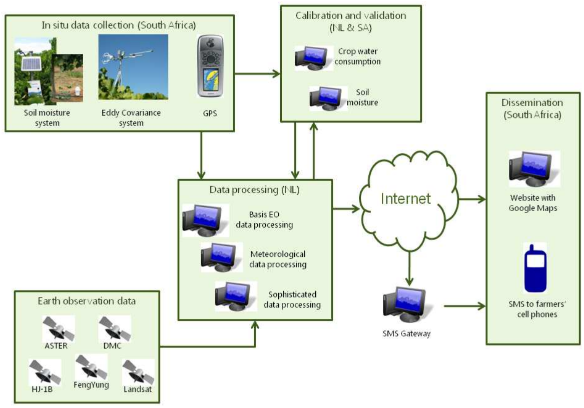

Figure 2: Global architecture of the system

Demonstration phase

The space assets utilised in the demonstration phase were: *1) Satellite Earth Observation*, *2) Satellite Communication*, and *3) Satellite Navigation.*

Multi-spectral and thermal infrared *satellite earth observation* data was obtained from the Huan Jing 1B (HJ-1B), Terra ASTER, Landsat 7ETM, Disaster Monitoring Constellation (DMC) and Fengyun sensors. The framework converts data of different satellite sources into standard maps of the Normalized Difference Vegetation Index (NDVI), surface albedo and surface temperature. The sophisticated data processing part of the system basically consists of three different algorithms: MeteoLook, the Surface Energy Balance Algorithm for Land (SEBAL) and IrriLook.

The algorithm MeteoLook spatially interpolates weather data from meteorological stations to a raster map using a physically based regional distribution model. The outputs of MeteoLook as well as the NDVI, surface albedo and surface temperature serve as inputs to SEBAL (Bastiaanssen et al, 1998[5], 2005[6]) which determines actual and potential evapotranspiration on a pixel-by-pixel basis. Besides crop evapotranspiration, SEBAL estimates biomass production, evapotranspiration deficit, leaf area index and the biomass water use efficiency. The weekly parameter layers produced by SEBAL consist out of raster images with a spatial resolution of 30 meters, which allow the identification of spatial differences within the vineyard block.

IrriLook is an irrigation advisory tool that provides 5-day forecasts on soil moisture in the root zone. The main inputs are SEBAL outputs and weather forecasts. As IrriLook computes the forecasts per block, information on the block boundaries is required. To acquire block boundaries for a number of demonstration farmers, a wide Global Positioning System (GPS) survey (*satellite navigation*) was executed in combination with aerial photography analysis. Through this survey 800 blocks were geo-referenced and inserted in the pre-operational data-base.

Figure 3: One of the seven satellite communication enabled soil moisture sensor installed in the grape farmer blocks

The in situ data provided calibration and validation datasets to assess the outputs of the algorithms. A *satellite communication* system was set up to transmit in situ soil moisture data from the vineyard to the framework. Seven ground sensors, integrating an SatCom Iridium modem and powered by photovoltaic generators were deployed on the participating farmer blocks (see Figure 3). Soil moisture was measured continuously at various depths in seven grape blocks and provided a better insight in how IrriLook was performing and how the models could be tuned in order to increase their accuracy. An Eddy Covariance system (Jarmain et al, 2009)[7] set up in a table grape block in Hex River valley evaluated the SEBAL estimates on energy fluxes.

Information Dissemination to Users

Data were delivered to the stakeholders through a website and SMS messages. Information on the parameters was made available to anyone interested on the website www.GrapeLook.co.za using a Google Maps interface (see Table 1 for the complete list of parameters). A group of demonstration farmers also received forecasts on soil moisture and irrigation water requirements; this information was provided on block level in graphs (see Figure 4). Additional to the website, which was accessible to anyone, a SMS service was set up for the demonstration farmers. These farmers received regular SMS messages on their cell phone with specific information on one to three pilot blocks. The SMS service was also used to inform the farmers about upcoming meetings and workshops.

Table 1 Delivery parameters grouped in growth, moisture, minerals and topography

Growth parameter	Unit
Growth	
Biomass production	Kg per ha per week
Leaf Area Index (LAI)	m^2 leafs per m^2 soil
Vegetation Index (NDVI)	-
Moisture	
Evapotranspiration deficit	mm per week
Actual evapotranspiration	mm per week
Crop factor	-
Biomass water use efficiency	Kg per m^2 of water
Minerals	
Nitrogen content in all leaves	Kilogram per ha
Other	
Aspect	

Table 2 Delivery parameters grouped in growth, moisture, minerals and topography

The dissemination website (www.GrapeLook.co.za), was updated weekly during the grape season of 2010-2011. Information on crop water, nitrogen and growth status at field level was made freely available online to anyone, whether working as a farmer, farmer consultant, irrigation expert or government official. The figure 4 shows an example of the main dissemination tool: the GrapeLook website.

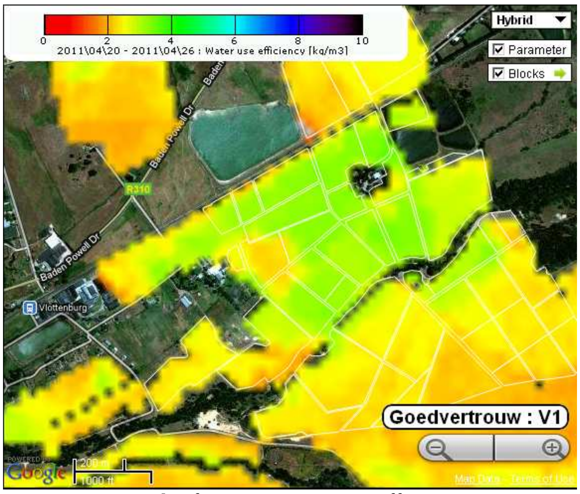

Figure 4*:* Example of Biomass Water Use Efficiency monitoring (GrapeLook website Stellenbosch area – 20/04/11)

The system focused on the vineyards (1) around the cities of Stellenbosch, Somerset West, Paarl, Wellington and Franschoek in the Berg River catchment; (2) around Worcester and De Doorns in the Breede River catchment; and (3) around Citrusdal, Vredendal and Klawer in the Olifants River catchment, as shown in the map in Figure 1. The total Area of Interest covered by vineyards in the project extended to 1700 km^2.

GRAPELOOK PROJECT ACHIEVEMENTS

Basically the GrapeLook project had two major outcomes: (1) the development of the system behind the pre-operational service, and (2) the demonstration of the service to the users. The website www.GrapeLook.co.za is crucial in this context as it links the system to the users.

The strength of the system is that it can operate by using different earth observation satellite resources to be independent from a single source. For example, after the earthquake in Japan the delivery of ASTER imagery was delayed, to which the system responded by using earth observation data of other satellites.

The system providing the information on the website developed within the project combines three space assets (satellite earth observation, navigation and communication). Earth observation data from different satellite sources was combined with satellite navigation and satellite communication systems, and was validated using in situ soil moisture and Eddy Covariance measurements.

The demonstration of the service encompasses three elements: (1) training of the users in using the service, (2) promoting the service, e.g. ‘spread the word’, and (3) collection of feedback of the users to improve understanding of the users’ needs, expectations and capabilities.

The main purpose of GrapeLook was to provide farmers with a deeper insight in the temporal and spatial processes on their farm. During workshops and farm visits, farmers received training, e.g. on how information on the spatial variability allows high precision water and fertilizer management and reduces the number of field visits and field samples required.

The feedback collected from questioned farmers about the benefits of the pre-operational service can be summarized as follows:

- The weekly updates are very useful to show water stress, delayed growth or when blocks need pruning to control vigour, and to identify irrigation system failure at an early stage;
- It was stressed that the comparison of the different parameters between and within seasons helps evaluating farm management and identifying more efficient practices;
- The GrapeLook service will help reducing labour and input costs and improving the water use efficiency, product quality, yield and profits by monitoring the irrigation efficiency.

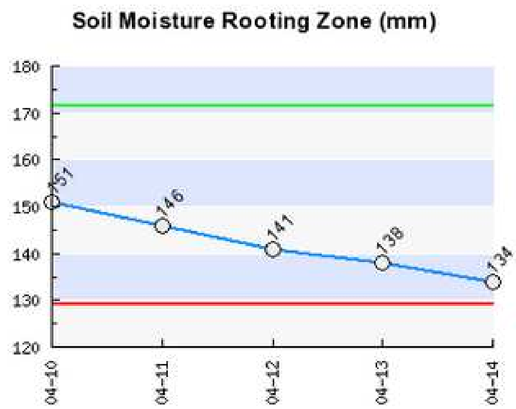

Figure 5: Example of soil moisture forecast for irrigation guidance (GrapeLook website block 5301 – 10/04/11)

During the project an inventory was made of participating farmers and farmer organisations, and contacts with water user associations, consultants and governmental organisations were established. The established contacts were used to inform the farmers about the GrapeLook service and workshops.

The demonstration project convinced the Department of Agriculture: Western Cape that GrapeLook is a very cost effective tool in improving water use efficiency. The information provided was exactly what was anticipated by the Department, although they feel the access to the website in rural areas needs improvement.

GrapeLook received also considerable attention in the media. The KykNet channel, a TV show aimed at the agricultural sector, broadcasted a program on the sustainability of grape framing in the Western Cape in the early morning of June 21. The availability and optimum use of irrigation water formed the basis of the program, in which Andre Roux of the DoA presented the GrapeLook results. On July 1, Radio RSG (Radio Sonder Grense, the Afrikaans service of the SABC) with close to 1 million listeners broadcasted an interview with Andre Roux on GrapeLook. The farmer magazine of South Africa Landbouweekblad published a 3-page article on the GrapeLook project "Ruimte-oe meet wingerdwater" by Johan Coetzee on May 13, 2011 (issue 1703). The magazine of the South African Irrigation Institute SABI covered the GrapeLook project in their volume 3, issue 4, 2011, with the title "The intelligent pixel – helping the farmer: water use efficiency".

The feedback of the users also resulted in a better insight into more specific needs and requirements of the grape farmers in Western Cape that will be used to further develop the service.

KEY LESSONS LEARNT

Refinement of the system and its elements took place during the demonstration phase. Among the key lessons learnt was that an operational service should be reliable in terms of data quality and delivery. To avoid (human) errors and ensure constant data quality a system such as GrapeLook requires a framework in which all data is processed similarly and procedures are automated where possible. Furthermore algorithms require continuous calibration and validation. The validation of SEBAL with Eddy Covariance measurements resulted in an improved SEBAL version.

It was also learnt that the success of dissemination is strongly correlated with the user friendliness and speed of the website. During the demonstration project, a number of measures were taken to increase the website speed, such as subdividing the data into regions to reduce the data load, the removal of small blocks in the soil moisture forecasts and hosting the website data on a faster server.

The system turned out to be robust and reliable in terms of (satellite) data collection/processing and running the algorithms and models. The dissemination of the data was however problematic from a technical point of view. The data dissemination scheme through the website could be enhanced. Many users in Western Cape have slow and unreliable broadband internet connections which were not suitable to download the required data on www.GrapeLook.co.za. To use the website and zoom into his farm, a farmer needs to download data for an entire region, which had major drawbacks on the website speed.

The lesson learnt is that the website should have a registration structure, in which users login and download the data of their own farm only.

Users all have different needs, expectations and capabilities and during the user evaluations a number of suggestions were made to improve the dissemination tool. For example, users were missing a tool to easily compare data of different weeks. They also requested an explanation of the parameters and suggestions next to the Google Maps interface instead of at a separate webpage.

Farmers are unlikely to adapt new technologies once the season started, as they have already chosen a certain management strategy and are fully focused on day to day farm management. Also awareness of users on the project was lower than anticipated, as many farmers do not attend farmer workshops and meetings in the middle of the season. Farmer meetings should be scheduled in August and September, before the season has started. To increase farmer awareness and participation in the next years, existing farmer networks should be used 'to spread the word' and training should start early in the season.

Another aspect to keep in mind is that GrapeLook provides information, not advice. To translate the information into a farm-specific advice, one needs knowledge on the farm and its objectives. Not all users are capable of translating the provided information to advice. An important role lays here for the farmer advisors and consultants. For example, a farmer could opt to send the GrapeLook information directly to his advisor/consultant to get a farm-specific advice.

STRATEGIC PLAN FOR THE FUTURE

The demonstration phase, which ran from September 2010 until April 2011, proved the technology could be applied on a weekly basis and that the end-users were supportive of the service.

It however also showed a number of opportunities for improvement of the current structure that will be tackled in the next season. First of all, the implementation of a registration (login) feature on the website will improve the download speed tremendously because a farmer will only download the data of his farm. Secondly, many grape farmers also grow deciduous fruit crops and pointed they would like to include these crops too. GrapeLook could easily expand to deciduous fruit trees as their growing season is overlapping with grapes.

Thirdly extending the study area to the areas south and north of Worcester (around Ceres and Grabouw) will include more fruit farmers and further increase market size.

In the coming years, the pre-operational service GrapeLook will roll-out into a commercial service. Critical in the adoption of the GrapeLook service will be trust and word-of-mouth advertising. Farmers are willing to adopt new technologies but first want prove that the benefits are worth the investment. Also the impact of ‘farmer talk’ should not be underestimated and properly utilized. The demonstration farmers will serve as early adopters, and are expected to bring in other users.

It is expected that it will take a few years before GrapeLook will be fully commercial as it takes time to build trust and awareness. The South-African authorities are aware of this, and are willing to provide the necessary funds to prolong a freely available GrapeLook service for another season. Based on the results achieved so far, WaterWatch expects to provide a commercial service that will be fully operational and for which farmers will share the costs.

ACKNOWLEDGEMENTS

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