WATER RESEARCH COMMISSION

TERMS OF REFERENCE FOR A DIRECTED PROJECT

KEY STRATEGIC AREA 4	**:** Water Utilisation in Agriculture (KSA4)
THRUST 3	**:** Water Utilisation for Poverty Reduction and Wealth Creation in Agriculture
PROGRAMME 1	**:** Sustainable water-based agricultural activities in rural communities

TITLE: Estimating and mapping cultivated areas, crop water use and yield through integrating machine learning and remotely sensed data for improved decision support systems.

Rationale

Food and water insecurity challenges in South Africa are being compounded by the increasing temperatures and drought occurrences at a time when demand for the same resources is also increasing due to population growth and urbanisation. The need to meet the food requirements of a growing population will continue to intensify current water stress challenges as more freshwater resources are directed towards food production under climate change. Recent studies have shown an increasing demand for irrigation water in recent years due to the need to maintain or increase agricultural productivity. The warming climate is exacerbating the challenge of water scarcity, which has resulted in increased aridity and shifts in agro-ecological zones and thus, affecting crop yields. This is happening at a time when irrigation is already using more than 60% of the available freshwater resources in the country. Thus, climate change and the increasing demand for food are driving huge transformations in irrigated agriculture, changes that require innovative approaches that improve water use efficiency and enhance crop productivity, so as to avail water to other sectors and enhance food security. Consequently, there is an urgent need for accurate information on the spatial extent of irrigated agriculture, information that remains scant at the moment.

Accurate irrigated area maps are critical for informing policy and decision-makers on formulating coherent and transformative strategies capable of turning irrigation into an indispensable climate change adaptation strategy, and also for providing near accurate yield estimates. Besides, accurate information on the extent of irrigated areas goes beyond the management of water resources, as its importance cascades into the water and food security, and the assessment of the impact of climate change on the agricultural sector. Existing irrigated area datasets developed at varying spatial scales and resolutions, include the FAO (Food and Agriculture Organization of the United Nations) database (Siebert et al., 2013), the Global Map of Irrigated Areas version 5 (GMIA 5.0) (Siebert et al., 2015), the MIRCA2000 product (Portmann et al., 2010), and IWMI's (International Water Management Institute) irrigated area map (Thenkabail et al., 2007). In 2016, IWMI further developed an improved irrigated area map for Asia and Africa using canonical correlation analysis and time-lagged regression at 250 m spatial resolution for 2000 and 2010 (Siddiqui et al., 2016). Although these datasets are important for indicating irrigated areas, they generally over-estimate the areas due to the low resolutions used. A recent study in South Africa has shown how low-resolution irrigated areas datasets over-estimate irrigated areas, particularly in smallholder fields where the crop fields are generally very small (Nhamo et al., 2020b).

However, recent advances in remote sensing technologies in conjunction with the emergence of big data and cloud management platforms like the Google Earth Engine (GEE) are facilitating the classification of near-accurate irrigated areas in a time and cost-effective manner, enhancing the monitoring of irrigated areas at both local and global scales. This is aided by freely available high-resolution remotely sensed products such as Sentine-2, as well as novel non-parametric machine learning algorithms for landuses classification. Supervised image classification machine learning algorithms include Support Vector Machine (SVM), random forest (RF), decision tree algorithms, and extreme gradient boosting (XGboost). Managing huge volumes of remotely sensed data and products is increasing becoming insurmountable, particularly when using traditional storage and processing techniques. These tedious, cumbersome, and slow pre-processing, processing, and post-processing traditional approaches are being replaced by these novel machine learning algorithms that are embedded in cloud computing big data platforms such as GEE. The GEE provides access to multi-petabyte of remotely sensed spatial datasets, enabling their timely geo-processing using machine learning algorithms and batch processing through programming languages.

Overall aim:

Monitoring irrigation water demand and consumption, as well as estimating crop yield, require accurate mapping of both rainfed and irrigated areas to facilitate informed policy formulations that enhance equitable water allocation, irrigation planning and drought and relief preparedness. Accurately mapped cultivated areas have become critical in recent years due to the need to achieve food self-sufficiency and at the same time be water-secure amidst the challenges brought about by climate change. This has resulted in increased developments in irrigation facilities in recent times. However, developments in irrigated agriculture are exacerbating water stress due to increased demand. This project seeks to apply machine learning algorithms to map near accurate irrigated areas, estimate crop water use and yield using high-resolution satellite images and GEE. The premise is to develop a spatial decision support system that assists policy and decision-makers to make informed assessments on crop water requirements, water allocation, agricultural land planning, crop yield, crop evapotranspiration patterns, basin hydrology, and the impact of different types of irrigation at both sub-catchment and national level in South Africa.

Specific objectives:

i. To classify irrigated and rainfed areas in South Africa using a combination of machine learning algorithms, high-resolution images, and GEE.
ii. To estimate annual crop water use and crop water productivity in South Africa.
iii. To estimate crop yield every year and inform policy and decision-making on coherent adaptation and resilience strategies.
iv. To develop a decision support system for estimating crop yield, consumptive water use, crop water evapotranspiration and crop water productivity and update cultivated areas (both irrigated and rainfed).
v. To develop guidelines of the developed decision support systems for use by relevant stakeholders.

Deliverables:

South Africa faces huge challenges of water and food insecurity, and the challenges are compounded by climate variability and change, population growth and urbanisation. There is need for proactive interventions by informing policy decisions that enhance preparedness, adaptation, and resilience. Technological advances, coupled with freely available remotely sensed products are facilitating the development of tools and products that improve the mapping of rainfed and irrigated areas, estimating crop yield and crop water use in near real time. These have become important for drought and other climate hazards preparedness and proactive interventions to reduce risks and vulnerabilities. These project aims to develop machining learning decision support tools that support decisions through accurate data on rainfed and irrigated areas, water quality and quantity, crop yield estimates, crop water productivity, consumptive water uses and water use efficiency. These products will be developed at the national level. The product will also enhance other national initiatives such as drought early warning and preparedness, relief interventions, among others. The Water Research Commission aims to support these national initiatives and enhance adaptation and resilience in both the agriculture and water sectors. As it is most unlikely that a single organization will have all the expertise required, it is strongly recommended that a consortium of experts and organizations, including public and private partners be formed and respond to this call and work towards a national crop yield, crop water use and hydrology system through machine learning and other clouding computing systems. Ability to demonstrate leverage funding and integration with ongoing activities will be advantageous as it strengthens the feasibility and sustainability of interventions.

Impact Area:
Empowerment of Communities and other related Knowledge tree impact areas
Sustainable development and redress
The estimated budget over a 36-months long study period is available from KSA 4.

Time Frame	**: 3 yrs.**
Budget for 1st year	**: R 1 000 000.00**
Retention payable on approval of final deliverable	**: R 500 000.00**
Total Funds Available	**: R 2 500 000.00.**

Budget breakdown:

AVAILABLE BUDGET OVER THE PROJECT PERIOD OF FOUR YEARS: **R 2 500 000.00**

2021/2022:	R 1 000 000.00
2022/2023:	R 1 000 000.00
2023/2024:	R 500 000.00
Total	**R 2 500 000.00**