WATER AND AGRICULTURE

Resource use efficiencies in potato production

Can South Africa produce more potatoes with less water? A current study investigates. Article by AC Franke, JM Steyn, ATB Machakaire, and AJ Haverkort.

Potato, the most important vegetable crop in South Africa, is produced in many distinct geographical regions differing in climate, soils, production seasons, management practices and access to markets. These differences affect the amount of input resources required to produce potato as well as yields and crop value, and therefore the use efficiencies of inputs.

Potato production in South Africa takes place on about 50 000 ha, with 92% of the production area under irrigation. The availability of irrigation water is limiting potato production in almost all production regions, but especially in those areas relying on borehole water (e.g. in Limpopo, North West and the Sandveld).

While potato is a high-value crop and important to rural economies, its production in South Africa is associated with several sustainability issues. The crop requires a high input of water, nutrients and biocides and due to potato's shallow root system, its production entails a risk of high levels of water drainage and nutrient leaching. Moreover, potato is often produced in areas with a high biodiversity value (e.g. the Sandveld situated in the Fynbos region) and due to the long

rotation farmers use to suppress pests and diseases, land use for potato production is much higher than the actual area under potato at any time.

The main potato production regions in South Africa.

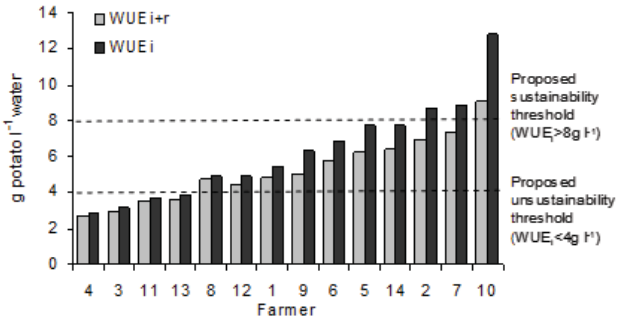
Resource use efficiencies, which are often expressed as the amount of yield produced for a certain amount of resource applied or consumed, are useful indicators of the ecological and financial sustainability of crop production. Comparing resource use efficiencies of farmers among each other can indicate the potential for improving efficiencies and help in identifying inefficiencies in the production system.

Moreover, relations between resource use efficiencies can help in unraveling the nexus between different sustainability indicators. Several projects, funded by Potato South Africa and the Water Research Commission, have contributed to assessing and understanding the variability in ecological resource use efficiencies achieved by potato farmers in South Africa and the impacts thereof on the environment. These projects conducted interviews with farmers and detailed measurements in the field.

Resource use efficiencies vary widely among farmers between regions but also within regions where farmers produce under relatively homogeneous agro-ecological conditions. For example, the observed water use efficiency achieved by farmers in the Sandveld varied from 2.9 to 12.8 g potato tuber produced for every litre of irrigation water applied. This wide variability within regions indicates a great potential for the majority of farmers to improve their resource use efficiencies. Moreover, the observed variability helps in setting sustainability norms where the best performers set a benchmark and indicate what is attainable when best crop management practices are applied.

As potato production regions in South Africa differ widely in climate, soils and production seasons, input use and resource use efficiencies also greatly differ between regions. In general, sandy soils (e.g. in the Sandveld) are associated with higher water use and lower water and nutrient use efficiencies due to the poor ability of these soils to retain water and nutrients.

In regions such as Limpopo and North West, where potato is irrigated with borehole water and pumping costs make up a main component of the production costs, water use efficiencies tend to be high. In general, the scarcer and more expensive a resource, the more efficient farmers tend to use it. The amount of irrigation water applied and water use efficiency are not related to each other. Some low yielding farmers achieve good water use efficiency due to low irrigation rates, while some farmers applying high irrigation rates also achieve good water use efficiency due to excellent yields.



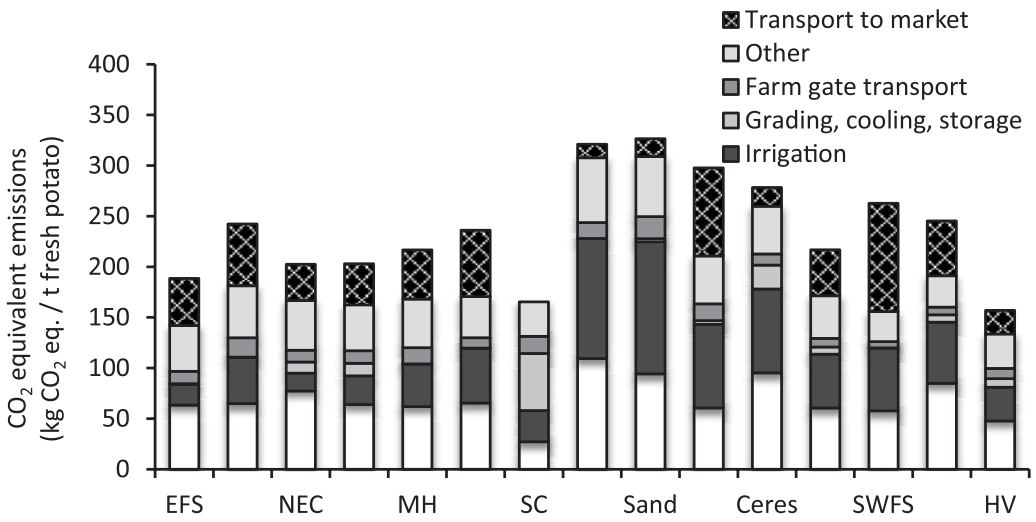
Water use efficiency (WUE, g potato l^{-1} water) of 14 potato farmers in the Sandveld region, based on irrigation water only (i) and irrigation and rainfall (i+r). Proposed sustainability thresholds are based on the relative performance of the farmers.

Average amount irrigated and water use efficiency (WUE) achieved by potato farmers in different production regions of South Africa, estimated from interviews with growers.

Production region	Actual amount irrigated (mm)	WUE (g potato l^{-1} water applied)
Ceres	774	6.4
Eastern Cape (EC)	393	7.0
Eastern Free State (EFS)	121	7.0
Gauteng (GT)	513	8.6
Highveld (HV)	270	12.2
Kwa-Zulu Natal (KZN)	263	9.1
Limpopo (Lim)	454	11.1
Loskop Valley (LV)	475	9.9
Northern Cape (NC)	400	8.0
North Eastern Cape (NEC)	228	7.8
North West (NW)	440	10.5
Sandveld (Sand)	604	7.8
Southern Cape (SC)	250	9.3
South Western Free State (SWFS)	550	8.7

The carbon footprint of potato production indicated below, used as a proxy for energy use and expressed in CO_2 equivalents emitted per ton of potato produced, is made up of fertilizer-related emissions, the energy costs of irrigation, product cooling during storage, transport and other emissions. Fertilizer-related energy costs are high due to the high energy requirements to produce fertilizer, especially nitrogen-based fertilizers, and due to the N_2O emissions from the soil stimulated by N-fertilizer applications.

Energy costs for irrigation are also substantial, especially when farmers irrigate from boreholes. Energy costs for transport of produce to markets are high for those farmers that are situated far from the main urban markets. A potato tuber consists for 80% of water, making it a bulky product to move around.



Main contributors to the carbon footprint of potato (in kg CO_2 equivalents per ton of tuber produced), averaged per production region in South Africa.

Photo supplied

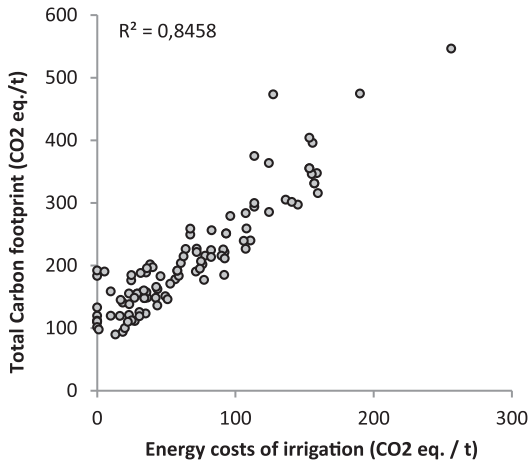
An eddy-covariance system measuring real-time evapotranspiration in a potato field.

Photo supplied

Potato production in South Africa gives high yields and requires high levels of inputs.

Resource use efficiencies are often related to each other and in potato production in South Africa water tends to be the key resource that drives use efficiencies of other resources. For instance, the energy costs associated with irrigation are largely determined by the amount of irrigation water applied and the vertical distance (depth of the borehole) the irrigation water needs to be pumped. While energy costs for irrigation make up around 25% of the total energy use in potato production and transport, these costs explain a large proportion (85%) of the variability in total energy costs.

Energy costs for irrigation are thus closely associated with the other contributors to energy use in potato. For instance, farmers who irrigate more than crop demand, tend to have a low fertilizer use efficiency due to leaching of nutrients and therefore high fertilizer-related energy costs. Probably farmers who achieve a high water use efficiency are generally those farmers who are 'on top of the ball' and produce efficiently in general.



The relation between the energy costs for irrigation and the total carbon footprint of individual potato farmers in South Africa.

To unravel the detailed interactions between environmental resource use efficiencies, we initiated detailed field measurements in potato-based rotations in the western Free State and in North West, using lysimeters to assess drainage and nutrient leaching and eddy-covariance techniques to measure evapotranspiration. We observed that water and nitrogen use efficiencies in potato are generally on the low side. However, the crop that follows potato, especially in case it is a deep rooting crop such as maize, can recover some of the water and a large part of the nitrogen leached by the previous potato crop making up for the low nutrient use efficiency and high leaching potential of potato. It shows that the environmental sustainability of crops should be assessed as part of the larger cropping system.

In conclusion, the large variability in resource use efficiencies observed among potato farmers, even within regions with homogenous agro-ecological conditions, indicates a great potential for many farmers to improve efficiencies and reduce pollution from agricultural activities. Intensive, high-input farmers that achieve high yields are not necessarily more, or less efficient in the use of resources compared to low-input farmers aiming for moderate yields. Water is clearly a key resource in potato production that affects the use efficiency of other resources. The use of decision support systems, such as irrigation scheduling tools, is thus key to improve resource use efficiencies.

Further information:

Franke AC, Steyn JM, Ranger KS, Haverkort AJ (2011) Developing environmental principles, criteria, indicators and norms for potato production in South Africa through field surveys and modelling. ***Agricultural Systems*** 104: 297-306.

Steyn JM, Franke AC, van der Waals JE, Haverkort AJ (2016) Resource use efficiencies as indicators of ecological sustainability in potato production: a South African case study. ***Field Crops Research*** 199: 136-149.

WRC Project no. K5/2501, Quantifying and managing agricultural nitrogen and phosphorus pollution from field to catchment scale.