ClimaAdapt

ADAPTATION TO CLIMATE CHANGE - An integrated science-stakeholder-policy approach to develop an adaptation framework for water and agriculture sectors in Andhra Pradesh and Tamil Nadu states of India

Water Use Efficiency measurements in irrigated agriculture

Johannes Deelstra, Krishna Reddy Kakamanu, Surresh Reddy, Kaluvai Yella Reddy,
Sai Bhaskar Reddy Nakka, Nagothu Udaya Sekhar

Problem description

Food production in India is to a large degree depending on irrigated agriculture. The increase in population, in addition to climate change, will have a significant impact on the available water resources. Limited water resources are available which implies that water use has to be made more efficient in the near future to provide food for a growing population. Traditional paddy rice cultivation needs large amounts of irrigation water. However, alternative systems for rice growth, such as the System of Rice Intensification (SRI) and Alternating Wetting Drying (AWD) are available having the potential for water saving compared to traditional paddy rice cultivation. This technical brief presents the methodology, used in the ClimaAdapt project, to get information about water use efficiency under different rice growing practices in the states of Andra Pradesh and Tamil Nadu.

Irrigation practices and different rice growing alternatives

With paddy rice cultivation, irrigation is practiced in such a way that the rice field is permanently flooded with a depth of water varying from 5 – 10 cm during the period after transplanting until 2 weeks before harvest. With SRI, no permanent standing water is present on the rice fields. During each irrigation, water is applied with a depth of water from 5 – 10 cm. Irrigation is applied a certain number of days after the disappearance of the ponded water. The system of AWD is a technique almost similar to SRI. Irrigation is applied almost similar to the SRI. However the next irrigation is applied when the groundwater level has fallen to 25 cm below the soil surface. Direct sowing is a technique, in which the seeds are sown directly in the field, with neither having a nursery a nor carrying out transplanting, as is practiced with SRI, AWD and paddy rice cultivation.

Groundwater observation well in AWD

In the ClimaAdapt project, water use efficiency is measured under both traditional paddy rice cultivation, SRI, AWD and direct sowing.

Water Use Efficiency (WUE)

In its simplest form water use efficiency (WUE) can be defined as yield per unit of water applied to the crop. To improve WUE, the yield per unit of water has to be increased. The amount of water applied can be interpreted as

a) amount of water lost through transpiration or evapotranspiration or
b) amount of water applied to the field through irrigation and precipitation

When considering (b) and in case irrigation water constitutes the major source of water for the crops, the WUE is very much linked to the irrigation efficiency. In the ClimaAdapt project, the water use efficiency is defined as the yield per unit of water applied to the field through irrigation and precipitation, as

$$WUE = \frac{crop\ yield(\,kg\ acre^{-1}\,)}{irrigation\ and\ preciptation\,(\,m^3\ acre^{-1}\,)}$$

However, the WUE calculated in this way can vary, depending on the size of the area beyond the location of water delivery to

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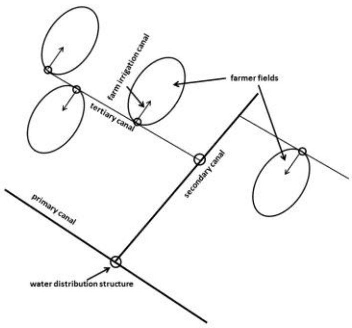
crops. The larger the area under consideration, the more the WUE is influenced by losses occurring in the irrigation system.



Layout of an irrigation canal system

Irrigation efficiency

Irrigation efficiency is defined as the ratio between irrigation water used by the crops and the water diverted from the source. Water is delivered through a network irrigation canals to the crops grown and loss can occur all along the way. Also, not all the water released to the field is used effectively by the crops. Some will pass the root system and leach to the groundwater while also losses can occur at the tail end of the farmer field. One differentiates between canal conveyance efficiency and field application efficiency. T*he conveyance efficiency (e_c)* expresses the loss of irrigation water in the canal system due to for example direct evaporation, percolation losses and losses at distribution points and tail ends of canals. The conveyance efficiency can vary from 60 % in earthen canals to 95 % in lined canals (FAO, 1989). The *field application efficiency (e_a)* is determined by the type of water application and defined as theratio of water stored in the root zone available for crop production and the amount of water delivered to the farm field. Different irrigation systems have different efficiencies, varying from 60 % with surface irrigation methods like border, furrow and basin irrigation to 90 % when practicing drip irrigation (FAO, 1989). *The overall scheme irrigation efficiency (e_o)* is obtained as the product of the conveyance and application efficiency and can vary from as low as 20 % to 60 %. Seckler (1996), states that traditional gravity irrigation systems have an overall efficiency in the order of 40%. Increasing the overall irrigation efficiency has a positive effect on the WUE as the same amount of crop will be produced with less water.

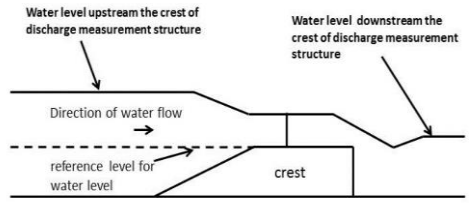
Water use efficiency measurements

Reliable information about the WUE can only be obtained when data about water delivery and yield are available. In both the Andra Pradesh and Tamil Nadu area a number of clusters, practicing different rice growing alternatives, have been selected. Measurements and observations are carried out to obtain information about WUE.

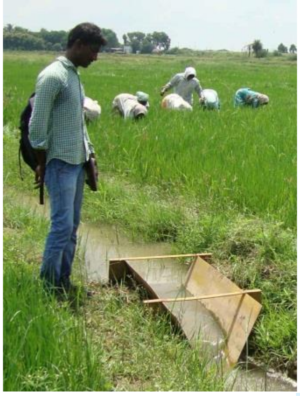
Water delivery measurement

The source of irrigation water to the farmer field can be from both irrigation canals and groundwater through bore wells. When water is applied through irrigation canals, the amount delivered to the field is measured using RBC flumes. In case the water application is through bore wells, a flow meter is used. When using a discharge measuring structure such as the RBC flume, it is important a head difference between the water upstream and downstream the crest is maintained (see box).

Box: Schematic view of water flow over an RBC flume.



Compared to other discharge measurement structures, an advantage of the RBC flume is its ability to operate under near submerged flow conditions with an allowable submergence ratio of up to 80%, i.e. the ratio of downstream water level to upstream water level



Well functioning RBC flume with a clear difference in water level

Poorly functioning RBC flume with no difference in water level

Errors in water delivery

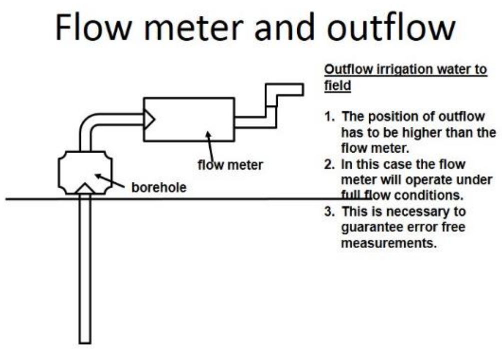
The total volume of water delivered to the farmer fields is calculated based on the duration of water application and the measured discharge. Manual recordings of the time of operation and discharge can lead to an uncertainty in water delivery to the field, its level though being unknown. The ClimaAdapt project will start using equipment to automatically record the discharge of the RBC flume, consisting of data loggers in combination with water level recorders. Comparisons will be carried out to assess the uncertainty in water delivery when using manual observations.

Water delivery measurement using flow meters

In case water is obtained from boreholes, water delivery is recorded using flow meters Flow meters can effectively measure the water delivery.

Flow meter installed on borewell

It is important however that the flow meter is operating under full flow conditions. Readings of the flow meter are carried out daily to obtain the daily water delivery to the field.



Proposed flow condition for flow meter

Additional measurements

In addition to the measurement of water delivery to the field, the days of irrigation application to the individual fields in the cluster are recorded, as well as the length of time of irrigation water application.

Accurate measurements of the total acreage of the cluster are available. On the basis of water delivery and acreage of the cluster, the amount of water per unit area, applied to the crop will be calculated and which forms an important element in the water balance of the rice crop.

Information about the obtained yield under different rice growing practices is obtained through farmer information. However also yield samples are taken by the project at several locations in the clusters

Detailed information about the dominating soil types has to be available, including soil profile descriptions, soil texture at different depth in addition to information about soil physical parameters at such as hydraulic conductivity and soil moisture retention. In addition is infiltration measurements needed. The soil data are necessary in further analysis on water balances under different rice growing systems

Evapotranspiration

Information on evapotranspiration will be obtained using local climatological data from the nearest weather station. The crop evapotranspiration will be calculated based on a combination of the reference crop evapotranspiration and crop coefficients (FAO, 1998). Crop water requirements will be calculated using the Aquacrop model. Also more advanced models are considered to be used.

Preliminary results

A change in irrigation practices for rice can improve water use efficiencies and potentially save water for use at other locations or for other purposes. The first results in the ClimaAdapt project have indicated that yields increase under alternative rice growing practices like while at the same time less water is used. The savings in water amounted to approximately 1163 mm for the cropping season, or ± 12 mm day^{-1}. However additional measurements have to be carried out as questions can be raised whether new rice growing practices really lead to water saving. Perry et al (2009) states that "water 'losses' at the scale of an individual field or an irrigation project are not necessarily 'losses' in the hydrological sense because the "lost" water may be available for use at some other point in the basin, or from an aquifer". Savings in irrigation water application through the implementation of new rice growing techniques does not necessarily have to mean a saving at the project level.

The new rice growing techniques can have a significant effect on the percolation losses from rice fields, especially on lighter soils. This could have an impact on the groundwater recharge and hence the operation of among others existing bore wells. These results of the ClimaAdapt project will be used by provincial governments to upscale WUE improvement programs across the provinces. An important aspect of the data collection also is its usage in different models which can be used in water balance calculations for different rice growing techniques.

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