Location	Nilo Coelho Irrigation Scheme Petrolina, Brazil
Contractor	EMBRAPA
Period	1998 – 2000

Scope of the project

The Nilo Coelho scheme with perennial fruit irrigation lies on the left bank of the San Francisco River in the state of Pernambuco, Brazil (latitude 09°09'S, longitude 40°22'W). The construction of the irrigation scheme was completed in 1990 and since then fruit trees are planted and agricultural business investments are made. Most orchards have a sub-surface drainage system. The San Francisco Valley Development Company (CODEVASF) is the governmental agency responsible for promoting the development of the river valley using irrigation as a propelling approach. The distribution of river water in Nilo Coelho is managed by the Nilo Coelho Irrigation District.

The water for the scheme is pumped from the huge Sobradinho reservoir at a maximum discharge capacity of 23.2 m^3/s. The minimum discharge released from the dam into the downstream San Francisco river is 2,070 m^3/s and the average discharge is nearly 3000 m^3/s. Hence, the Nilo Coelho scheme takes only 1% of the total river flow. More water resources could be developed downstream of the reservoir and there is ample room for expanding irrigated agriculture.

The purpose of the project was to demonstrate how irrigation management can be improved with use of low-cost and low resolution satellite measurements complemented with field data on water flows and rainfall in a modern and commercialized irrigation scheme in Northeast Brazil.

Approach

The International Commission on Irrigation and Drainage (ICID) published a long list of proposed performance indicators to evaluate irrigation and drainage projects. From this proposed standard terminology, a 'short-list' of indicators was composed following consultation with the irrigation managers, and experts from the Brazilian Agricultural Research Organization, EMBRAPA. This short-list was compiled to support the local water distribution decision making. The proposed ICID terminology was followed whenever possible. Other indicators are proposed also (see table 1).

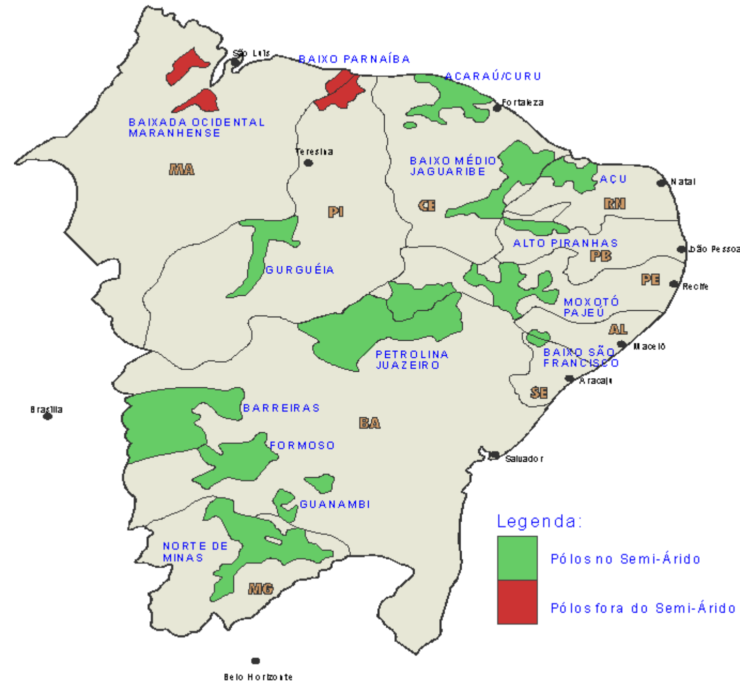


Figure 2: location of major irrigation schemes in north-east Brazil. Nilo Coelho is located in the center (Petrolina Juazeiro)

Table 1: Formulation of irrigation performance indicators applied in the current study in the Nilo Coelho scheme

Irrigation performance indicator	*Mathematical expression*
Relative water supply	$(P_{gross} + V_c) / ET_{pot}$
Overall consumed ratio	$(ET_{pot} - P_e)/V_c$
Depleted fraction	$ET_{act}/(P_{gross} + V_c)$
Crop Water Deficit	$ET_{pot} - ET_{act}$
Relative evapotranspiration	ET_{act} / ET_{pot}
Relative soil wetness	Θ / θ_{FC}
Biomass yield over irrigation supply	Bio / V_c

P_{gross} = gross precipitation (mm/month),
P_e = effective or net precipitation (mm/month),
V_c = water delivery from the (river or) reservoir (mm/month),
ET_{act} = actual evapotranspiration by irrigated crops (mm/month),
ET_{pot} = potential evapotranspiration by irrigated crops (mm/month),
Θ =Volumetric soil water content in the rootzone (cm^3/cm^3)
Θ_{FC} = Volumetric soil water content at field capacity (cm^3/cm^3)
Bio = crop growth expressed as above ground dry bio-mass growth (kg/ha per month)

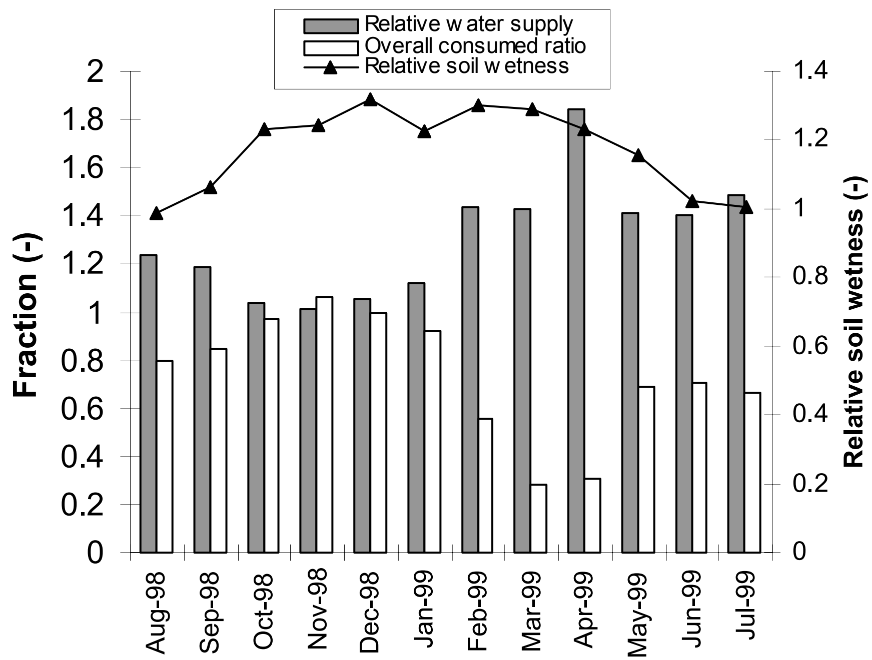
The NOAA satellite data were used to determine monthly values for actual evapotranspiration, biomass production and soil moisture using the Surface Energy Balance Algortihm for Land (SEBAL). The SEBAL results have been complemented with field data. CODEVASF has an extensive flow-measuring network; flow data are collected and made available on a monthly basis. The availability of discharge measurements at all important off-take points is a unique situation which invites to thoroughly diagnose the pathways of irrigation water from the reservoir to the fruit crops.

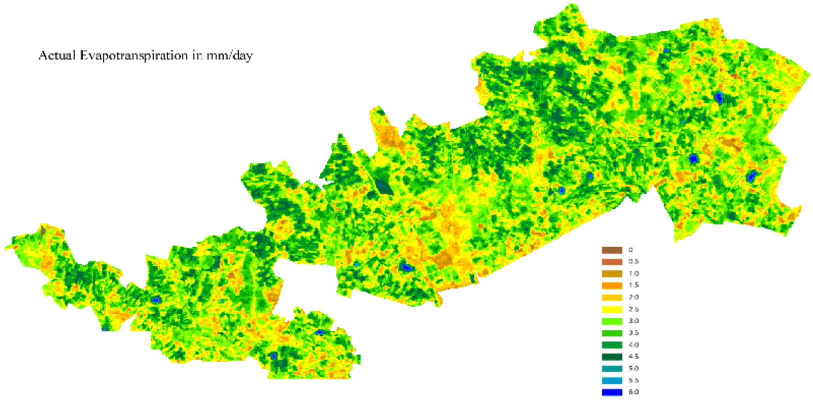
Results

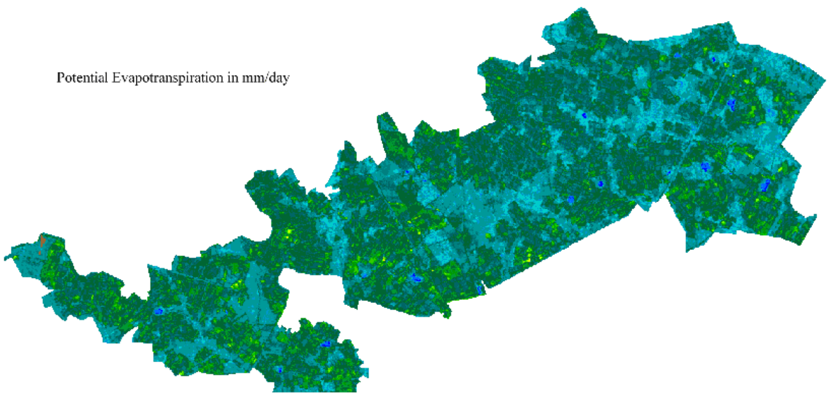
The evaporative demand of the atmosphere varies between 80 to 150 mm/month. The irrigation water supply should therefore correct for seasonal changes of the potential evapotranspiration. This is the rationale behind using the *relative water supply* as a performance indicator. Figure 3 shows a distinct variation of *relative water supply* with time. Some aspects need more attention:

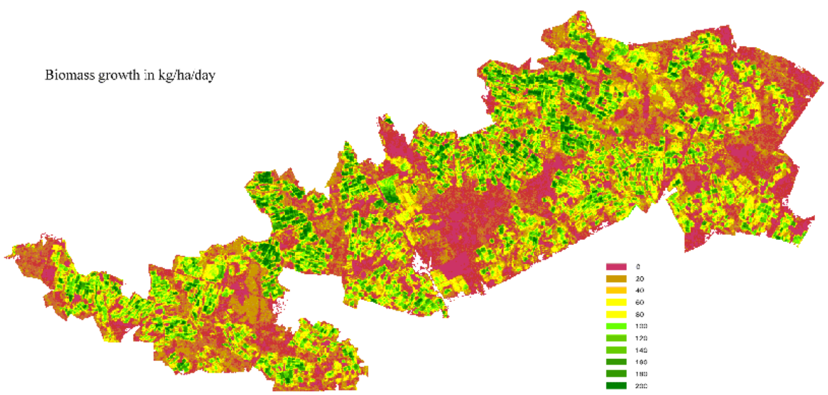
1) From Feburary till July, the *relative water supply* averages around 1.4 (exceeding 1.7 in April), whereas October through January is characterized by a *relative water supply* around 1.0. This implies that over-irrigation occurs between February through July. Irrigation water can be saved in this period and eventually supplied to the crops in other parts of the year.

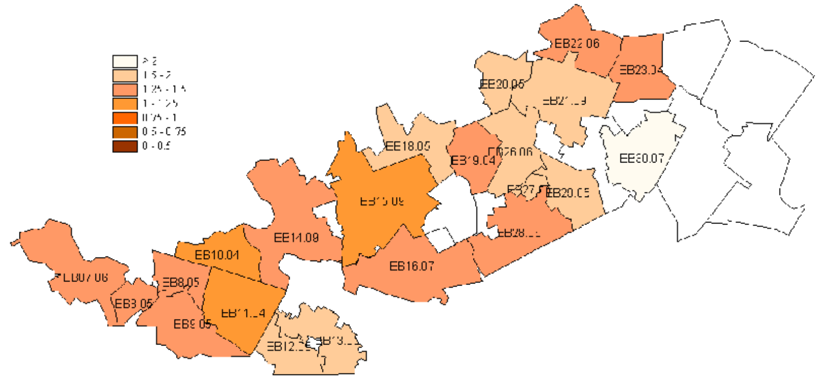
2) Re-allocation is however not necessary because *overall consumed ratio* and *relative water supply* are both adequate during August to January (Figure 3). The *relative water supply* and *overall consumed ratio* have an inversely proportional relationship, and proper irrigation management will tend them both towards one. During October to December a tendency to close the gap between *relative water supply* and *overall consumed ratio* can











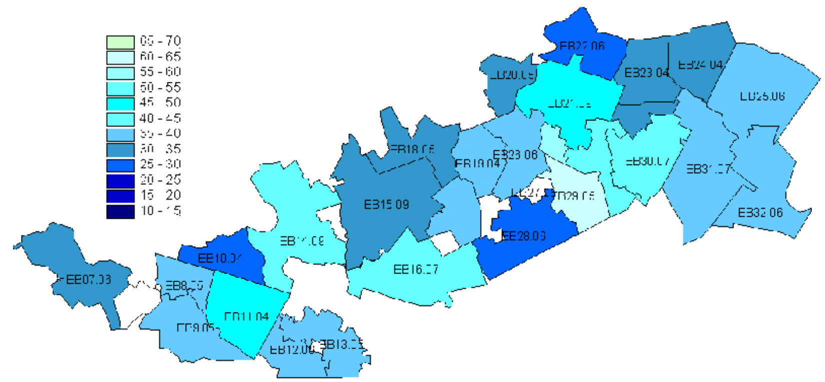


Figure 4: examples of products

Part A: actual evapotranspiration (mm/day)

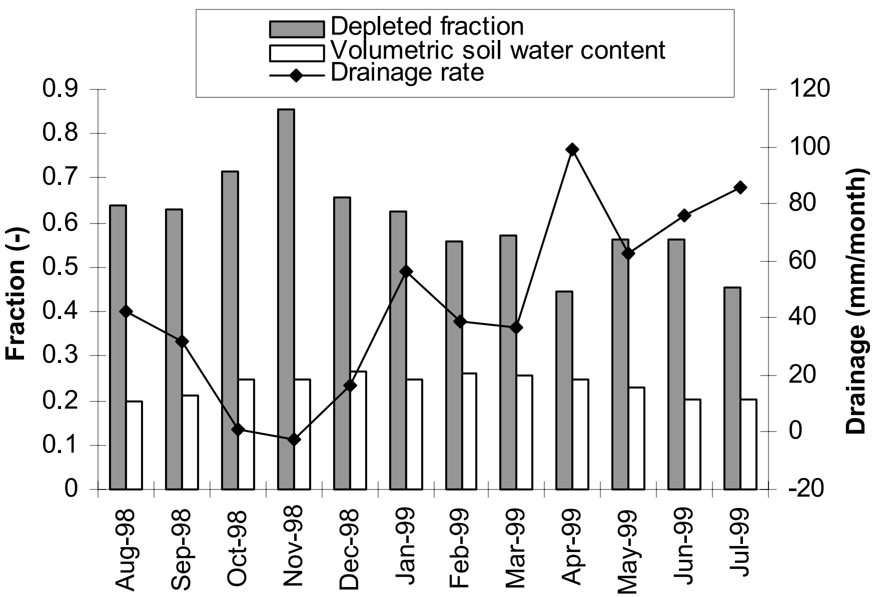
Part B: potential evapotranpiration (mm/day)

Part C: biomass growth (kg/ha/day)

Part D: relative water supply for May 1999 (dimensionless), and

part E: crop water deficit for January 1999 (mm/month) be witnessed. Most water is than effectively consumed by the fruit crops and the losses are less, whereas the soil is little above field capacity. October and November are school examples of how irrigation water should be managed and used without losses.

3) The average irrigation supply of 1339 mm exceeds together with a rainfall of 586 mm far the actual crop evapotranspiration. An *overall consumed ratio* of 0.7 can be met if 1000 mm irrigation supply is reduced to 1000 mm/yr. A reduction from 1339 to 1000 is equivalent to 25% savings in the irrigation water diversions.



4) The period February to April shows that maximum crop water use is less than half of the pumped irrigation water; a serious over-irrigation occurs. The result is that the soil water content is high and excess water is drained off.

5) Numerical model simulations with the Richard's equation has shown that a field capacity soil water content of 0.20 $cm^3\ cm^{-3}$ is typical for the sandy loam soils of Petrolina. The inter-annual fluctuations of soil moisture are minor, and the relative soil wetness is the whole year round 1 or more. This implies that the soil moisture remains at or a little above field capacity and that the expensive high precision irrigation and sub-surface techniques keep water in the root zone at adequate levels. This information is very important and implies that soil moisture management is optimal.

The performance indicators are calculated for all 31 lateral units served by a pumping station on a month-to-month basis (see figure 4). This performance statistics allow diagnosing the differences among the lateral units. One example is provided in Figure 5. The largest variation of RWS among the units occurs during May 1999. Pumping stations EB10.04, EB11.04 and EB15.09 under-irrigate with 0.75< RWS< 1.0 as compared to intended RWS values between 1.0 and 1.3. Pumping station EB30.07 shows the opposite performance with RWS > 3.0 revealing a waste of water and energy.

Recommendations

The spatio-temporal patterns of the irrigation performance indicators gave information on the functioning of the Nilo Coelho scheme. Although the scheme is well managed, this information was not available before. Remote sensing provides opportunities to retrieve new performance indicators such as *depleted fraction*, *crop water deficit*, *relative evapotranspiration*, *relative soil wetness* and *biomass yield over irrigation supply*. Another advantage is that potential evapotranspiration can be retrieved directly without the use of crop coefficients. This evades the need to use standardized K_c tables such as provided by Doorenbos and Pruitt. The proposed indicators give key information on the moisture status in the root zone and actual crop water use. The conservation of the water balance allows computing outflow from the root zone, i.e. drainage, as a residual term. This gives a more comprehensive description of the total system as compared to classical indicators describing water delivery and service levels.

In general, it is confirmed that one single performance indicator can neither describe deficiencies in the system management, nor ways to improve them. A combination of indicators enhances the diagnostic opportunities, especially when the entire flow path form the reservoir upto the stomatal cavity an be quantified.

WaterWatch
Generaal Foulkesweg 28
6703 BS Wageningen
The Netherlands

Tel: +31 (0)317 423 401
Fax: +31 (0)344 693 827
Web: www.WaterWatch.nl
E-mail: info@WaterWatch.nl