Annex 12:
Water Requirements Satisfaction Index methodology

To evaluate rainfall deficit hazard in Rwanda, the approach was to define occurrence of rainfall deficit relative to a crop specific standard. In this approach, one compares the water supplied by rainfall (or irrigation) against the water requirements of a particular crop as both components vary through the season. At the end of the season, a numerical index is formed, the WRSI (Water Requirements Satisfaction Index) which is 100 in case the crop water requirements are fully satisfied through the season and increasingly below this value the more the rainfall is unable to satisfy them.

This approach runs a simple water balance model with a 10 day time step. Rainfall is monitored from the beginning of the season and at each time step the rainfall (plus any water stored in the soil) is compared to the water requirements of the crop. If this exceeds the crop requirement, the excess is added to the soil; if it is below the crop requirements a deficit is registered.

Deficits are added throughout the season and at the end, the WRSI is calculated as:

WRSI = 100 – (Total Deficit / Total Crop Requirement)

This WRSI is 100 for seasons with an optimal water supply (no deficits) and would be 0 for no rainfall. In practice, values below 50 generally correspond to a complete crop failure.

The model is tuned to specific crops by using tables of seasonal water requirements published by FAO for specific crops. In this way, the behavior of crops with higher water requirements (maize) or longer development cycles is accounted for and differentiated from those of less water demanding crops (such as millet).

The crop water requirements vary through the season reflecting the crop development stages: they are lowest at planting time, increase steadily to reach a peak in the approach to maturity (during the crop flowering and grain filling period for cereals) and decrease again as the crop ends its development. They are specified by means of so called ***crop coefficients*** (Kc) which are fixed for a given crop and apply irrespective of where the crop is grown.

The crop coefficients are ratios of the crop water requirement and a parameter known as Potential Evapotranspiration (ETp) which measures the water demand imposed by the environment where the crop grows (through temperature, amount of sunshine, humidity, wind speed, etc,). So the crop water requirement (for a given stage of development) is derived as:

WR = Kc * ETp

The Kc contains the crop information while the ETp carries the local climate information. E.g. since a semi-arid climate (hot, sunny, windy and dry) will have a much higher ETp than a temperate climate (cool, cloudier, humid), a crop planted in a semi-arid climate requires more water than the same crop planted in a temperate climate.

Given that the required data exists as gridded datasets (rainfall, ETp, maximum soil water holding capacity) and tabled Kc values are available for a range of crops, the model can be run and its outputs produced as grids to be displayed as maps.

MODEL DETAILS

This model was run for Rwanda for a standard maize crop and for a standard bean crop, using gridded data sets of the required inputs – the rainfall data used as input is from the same source as in the previous section. The ETp data used were long term averages mapped at the same resolution and originating from USGS. The maximum soil water storage is derived from the FAO Soil Map of the World.

The model was run for the two cropping seasons in Rwanda (A and B). For season A, the model started running in August, while for season B it started running in March. For maize we allowed a 4 month development cycle, for beans a 3 month development cycle was allowed.

Water requirements for both crops were found in Allen et al (1998) [Allen, R.G., Pereira, L.S., Raes, D. and Smith, M., 1998, "*Crop evapotranspiration – Guidelines for computing crop water requirements*", FAO Irrigation and Drainage Paper 56 (Rome)]. Beans will require less water then maize, as they have a shorter development cycle and are less water demanding during key stages of the season.

It should be noted that besides requiring more water, maize is also far more sensitive to water stress than most other (cereal and tuber) crops, particularly during its flowering and grain filling stages. This means that for the same degree of water supply deficit, maize will suffer a larger decrease in final yield than another cereal crop growing under similar circumstances.

The occurrence of significant impacts on crop production is evaluated by deriving the magnitude and frequency of deviations of the WRSI from a reference value, its medium term average value. Deviations from the average are related to qualitative rainfall deficit levels as follows :

Mild rainfall deficit:	WRSI within 80-90
Moderate rainfall deficit:	WRSI within 70-80
Severe rainfall deficit:	WRSI below 70

The WRSI model was run for each season in the record (1995-1996 to 2009-2010). From the set of seasonal outputs, the long term average was derived and the ratios of the average derived for each season. This set was then converted into frequencies of occurrence.