Uncertainty of rainfall products: Impact on modelling household nutrition from rain-fed agriculture in Southern Africa

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Impact on modelling household nutrition from rain-fed agriculture in Southern Africa

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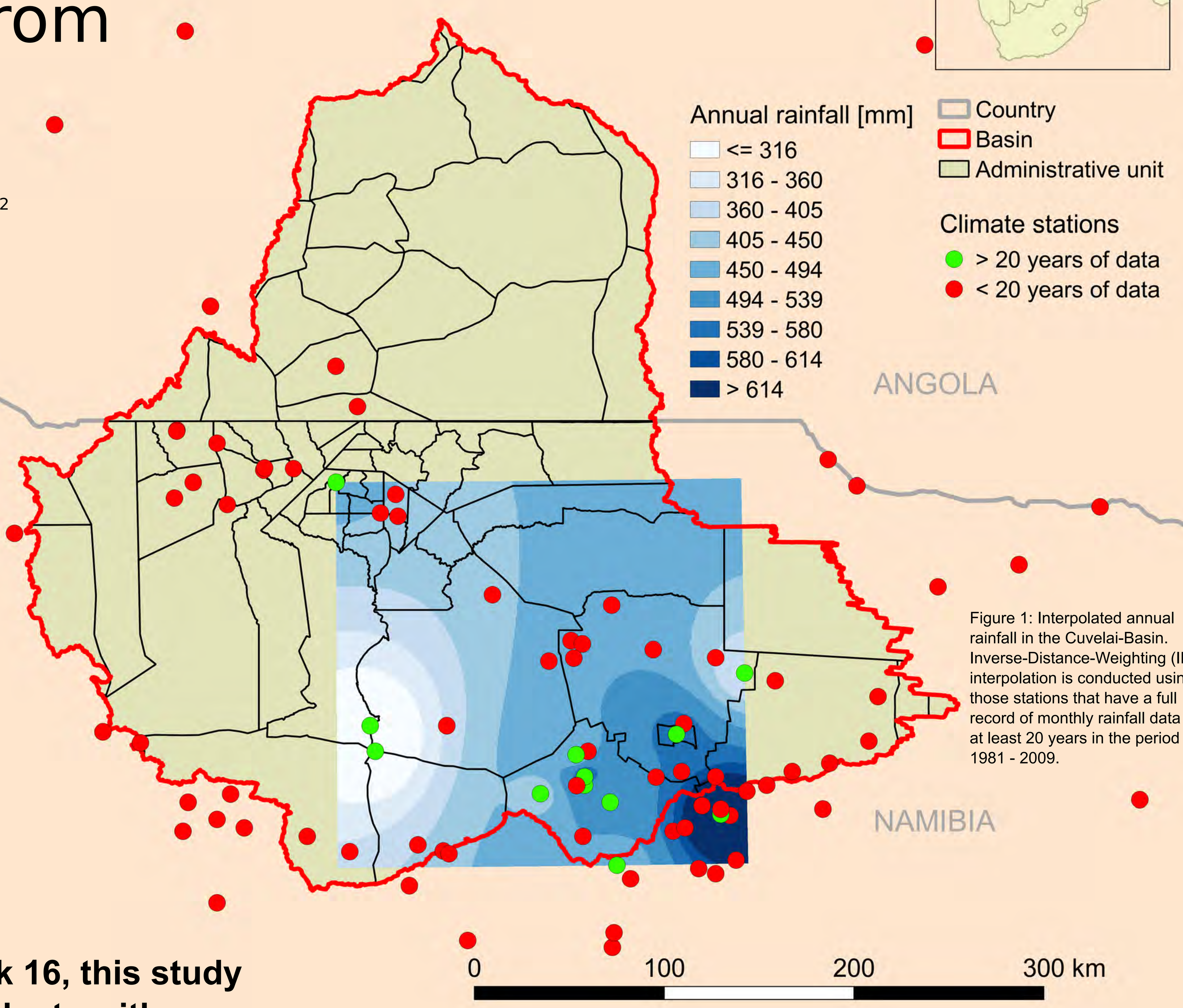

Figure 1: Interpolated annual rainfall in the Cuvelai-Basin. Inverse-Distance-Weighting (IDW) interpolation is conducted using those stations that have a full record of monthly rainfall data of at least 20 years in the period 1981 - 2009.

MOTIVATION

Good quality data on precipitation are a prerequisite for applications like short-term weather forecasts, medium-term humanitarian assistance and long-term climate modelling. In Sub-Saharan Africa however, the terrestrial climate station networks are frequently insufficient as in the Cuvelai-Basin in Namibia and Angola.

As part of SASSCAL task 16, this study analyses six rainfall products with respect to their performance in a crop model (APSIM) to obtain nutritional scores of a household's requirements for dietary energy and further macronutrients.

RAINFALL PRODUCTS

The use of rainfall products in data scarce regions is a popular approach in science for various purposes. Today, many products are available, differing in terms of platforms, sensors, processing algorithms, spatial and temporal resolutions, and auxiliary information. To contribute to the ongoing evaluation of these products in different regions, this study makes use of six publicly available products/datasets (Table 1).

Table 1: Rainfall products used in this study.

Product	Instrument	Spatial Cov.	Spatial Res.	Temporal Cov.	Temporal Res.	Provider	Reference
CHIRPS 2.0	IR,MW,RG	50°N-50°S	0.05°	1981-2015	d	UCSB,CHG	(Funk et al., 2015)
GPCCv7	RG	global	0.5°	1901-2013	m	DWD	(Schneider et al., 2015)
ARC 2.0	IR,RG	Africa	0.1°	1983-2015	d	NOAA	(Novella & Thiaw, 2012)
CRU-TS 3.23	RG	global	0.5°	1901-2013	m	UEA,CRU	(Harris et al., 2014)
TAMSAT	IR,RG	Africa	0.0375°	1983-2015	d	UoR	(Tarnavsky et al., 2014)
PERSIANN-CDR	MW,IR,RG	60°N-60°S	0.25°	1983-2015	d	NASA	(Ashouri et al., 2014)

(CHG = Climate Hazards Group, Cov. = Coverage, CRU = Climate Research Unit, d = daily, DWD = Deutscher Wetterdienst, IR = infrared, m = monthly, MW = microwave imager, NASA = National Aeronautics and Space Administration NOAA = National Oceanic and Atmospheric Administration, Res. = Resolution, RG = rain gauges, UCSB = University of California, Santa Barbara, UEA = University of East Anglia, UoR = University of Reading)

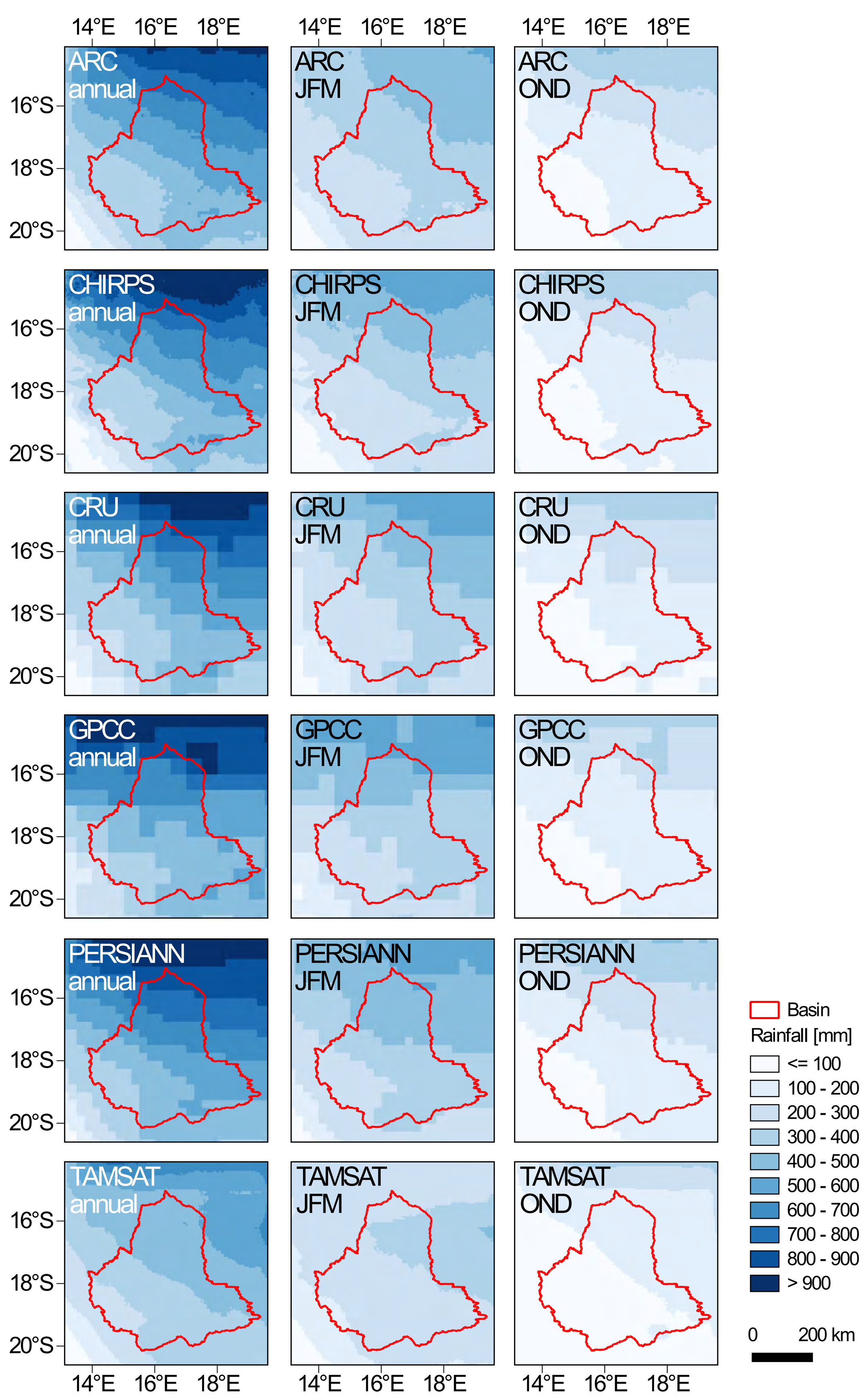

Figure 2: Spatial signal of mean rainfall. Left column: Mean annual rainfall; Middle column: Mean rainfall during first quarter (JFM); Right column: Mean rainfall during fourth quarter (OND). Second and third quarter do not show significant amounts of rainfall.

CALIBRATION & PROCESSING

All rainfall products are calibrated to the observed time series from Okatana station in northern Namibia using Quantile Mapping (QM) with parameter estimation on a monthly basis. The monhtly data products from GPCC and CRU are disaggregated from the monthly to the daily scale using the Cascade Model Approach prior to calibration. The calibrated time series well reproduce the observed precipitation characteristics in terms of dry spell duration, rainy day count and rainy season onset, among others. These calibrated data are used in the crop model Agricultural Production Systems sIMulator (APSIM) to estimate millet yield.

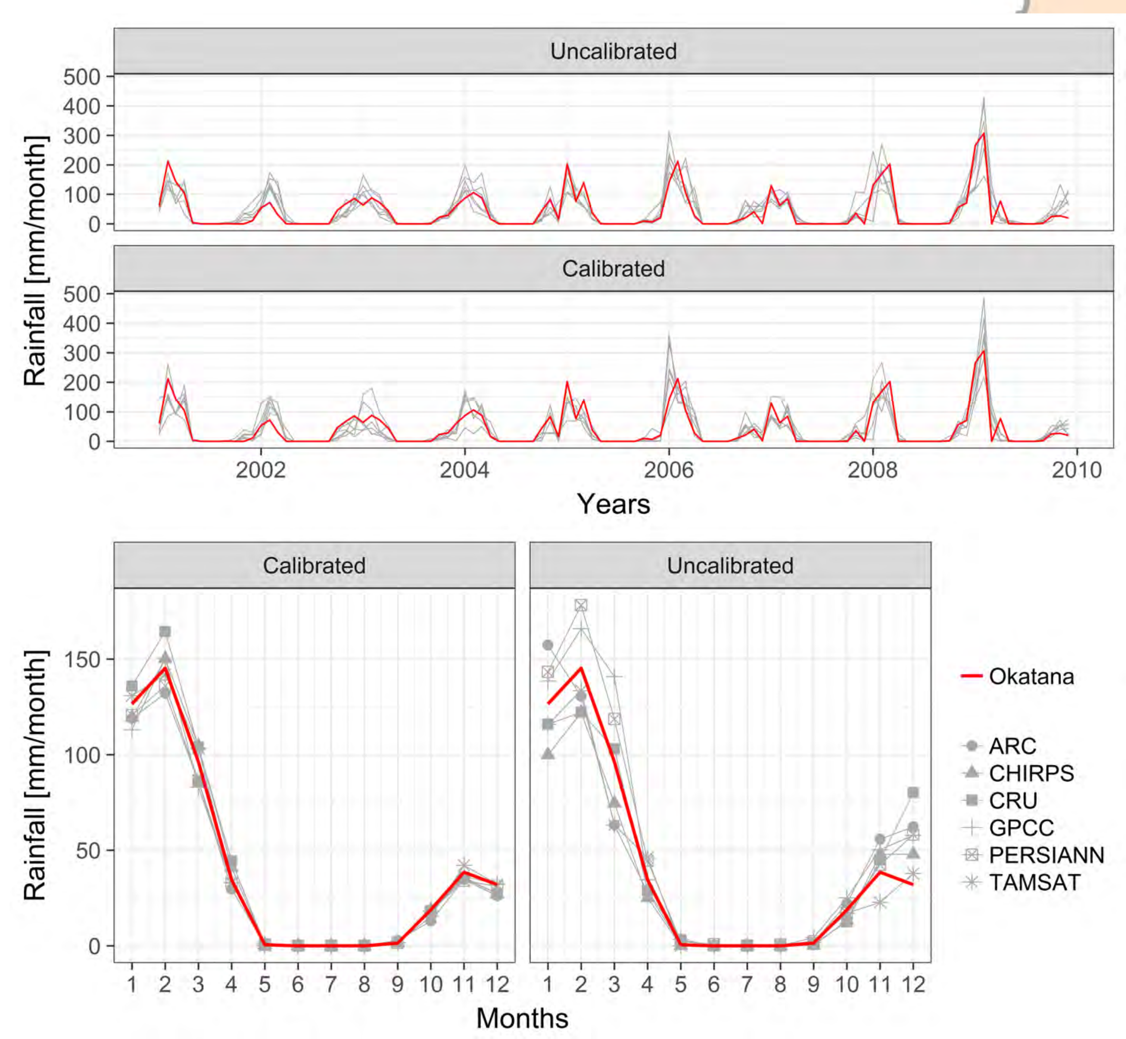

Figure 3: Calibration results for rainfall products. Upper plots: Uncalibrated and calibrated donthly rainfall between 2001 and 2009. Lower plots: Monthly average rainfall for uncalibrated and calibrated products. Red line indicates the observed data from Okatana station.

RESULTS

The interpolation results from available gauge stations in the Cuvelai-Basin highlight a deficit in the spatial endowment with climate stations. As a result, no reliable estimate on current and past rainfall can be obtained from the station network for the entire basin (Fig. 1). The use of rainfall products is therefore necessary to perform a range of applications. Overall, the results show that the products well reproduce the basin's spatial and temporal rainfall patterns (Fig. 2). In detail, estimated monthly rainfall at the location of Okatana station correlates well with the observed records (r = 0.84). QM calibration improves the rainfall statistics of the products and aligns them to the observed characteristics from Okatana station (Fig. 3).

Though calibration improves the fit of the products to the observed rainfall characteristics, differences persist resulting in varying crop model outcomes. The degree of fulfilment fluctuates around the total fulfilment of the dietary energy demand with an average of 97%. However, Fig. 4 shows large differences in 1987 and 2004. PERSIANN and ARC fail in generating yield as limited soil moisture prevents the crop from germination. Both products show longer dry spell durations and less rainy days compared to the observed data which might explain model failure. 1992 stands out in which all products point to low yield and hence a critical energy demand fulfilment of only 68%. This year is well known as a severe drought year, particularly affecting the agricultural production of the northern regions.

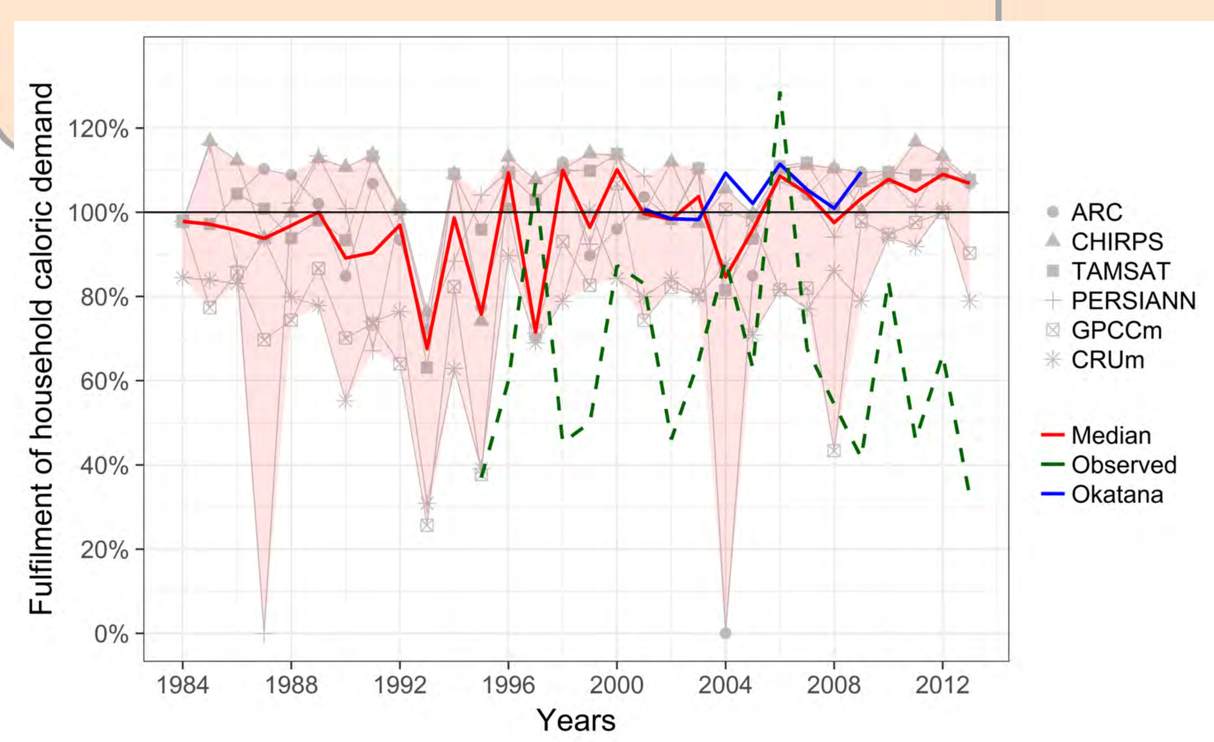

Figure 4: Fulfilment of a household's dietary energy demand. Results stem from yield estimates calculated by the APSIM crop model. Daily rainfall data from the products and Okatana station are used as input for the model. Results are compared to observed yield from northern Namibia.

TAKE HOME MESSAGE

Overall, this study makes contributions to the field of rainfall data analysis, agricultural modelling and food security monitoring. It shows that rainfall products entail uncertainties due to differences in sensors, algorithms, and spatial/temporal coverage and resolution. Though calibration enhances the fit to observed data, differences persist resulting in uncertainty of model outcomes. Hence, the selection of rainfall products must be made explicit in any application. Furthermore, the coverage of rain gauge stations in Sub-Saharan Africa is insufficient for a range of modelling and monitoring purposes. Prompt extension of the current station network is required as already attempted by SASSCAL WeatherNet.

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