

Adaptation and evaluation of the SARRA-H crop model for agricultural yield forecasting in West Africa

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Introduction

The West African Sahel is subject to climatic variations that make rainfed agriculture highly unreliable in areas with less than 600 mm per year (Sivakumar, 1989). The effects of droughts, associated with widespread poverty, lead to repeated food crises whose prevention and management require a close monitoring of crop growing conditions during the rainy season.

Since its creation in 1974, the AGRHYMET Regional Center has been using relevant early warning tools and methodologies to help CILSS member countries national authorities and their development partners anticipate such crises, and thus alleviate their negative effects on people. One of the tools used for that purpose is the DHC (Diagnostic Hydrique des Cultures) crop water balance simulation model (Samba et al. 2001). This model simulates crop water satisfaction on a dekadal basis and makes projections on potential yields 2 to 3 months before harvest. However, it does not perform well in all situations, particularly in relatively humid years/regions when it underestimates yields. To overcome these shortcomings and with the extension of AGRHYMET mandate to cover all West African countries, there was a need to upgrade the model. This was undertaken by adapting and evaluating a new model, SARRA-H, developed, as DHC, by CIRAD (France) in collaboration with some West African national agricultural research institutes.

SARRA-H is a deterministic model that simulates not only water balance, but also carbon balance and crop phenology. It reproduces well pearl millet growth, development and grain yield under optimal agronomic conditions (Alhassane 2009), but its performance needed to be evaluated in on-farm conditions.

Material and Methods

- Two types of agronomic trials were conducted in 2002 and 2003 at the premises of The AGRHYMET Regional Center, Niamey, to study the effects of sowing dates on the one hand, and that of nitrogen fertilization on the other hand, on the variations of the above ground biomass of two pearl millet varieties (HKP , 90 days) and MTDO (photoperiod sensitive).
- The first trial consisted in sowing the two millet varieties at two different dates to evaluate their photoperiod sensitivity, while the second trial compared the same two pearl millet varieties under two levels of nitrogen fertilization : 0 and 100 kg ha⁻¹ of urea.
- Phenological observations, as well as destructive measurements to monitor the evolution of above ground dry matter (leaves, stems and grains) were done periodically. An automatic weather station measured daily values of air temperature, relative humidity, solar radiation and wind speed to allow for the computation of PET using the FAO Penman-Monteith equation (Allen et al. 1998).
- Starting 2004, in the framework of the AMMA project, on-farm surveys were conducted in 10 villages within the Niamey squared-degree area (120 x 160 km fig. 1), to characterize millet yield spatial variability and evaluate the SARRA-H model. Thirty (30) farmer plots were selected in each village to record information on sowing dates, fertilizer use (type, application time and amount), crop variety, damages caused to the crop and final grain yield.
- The performances of the SARRA-H and the DHC4 models were evaluated by comparing the results of their respective simulations with observed millet yields in the 10 villages over 7 years (from 2004 to 2010).

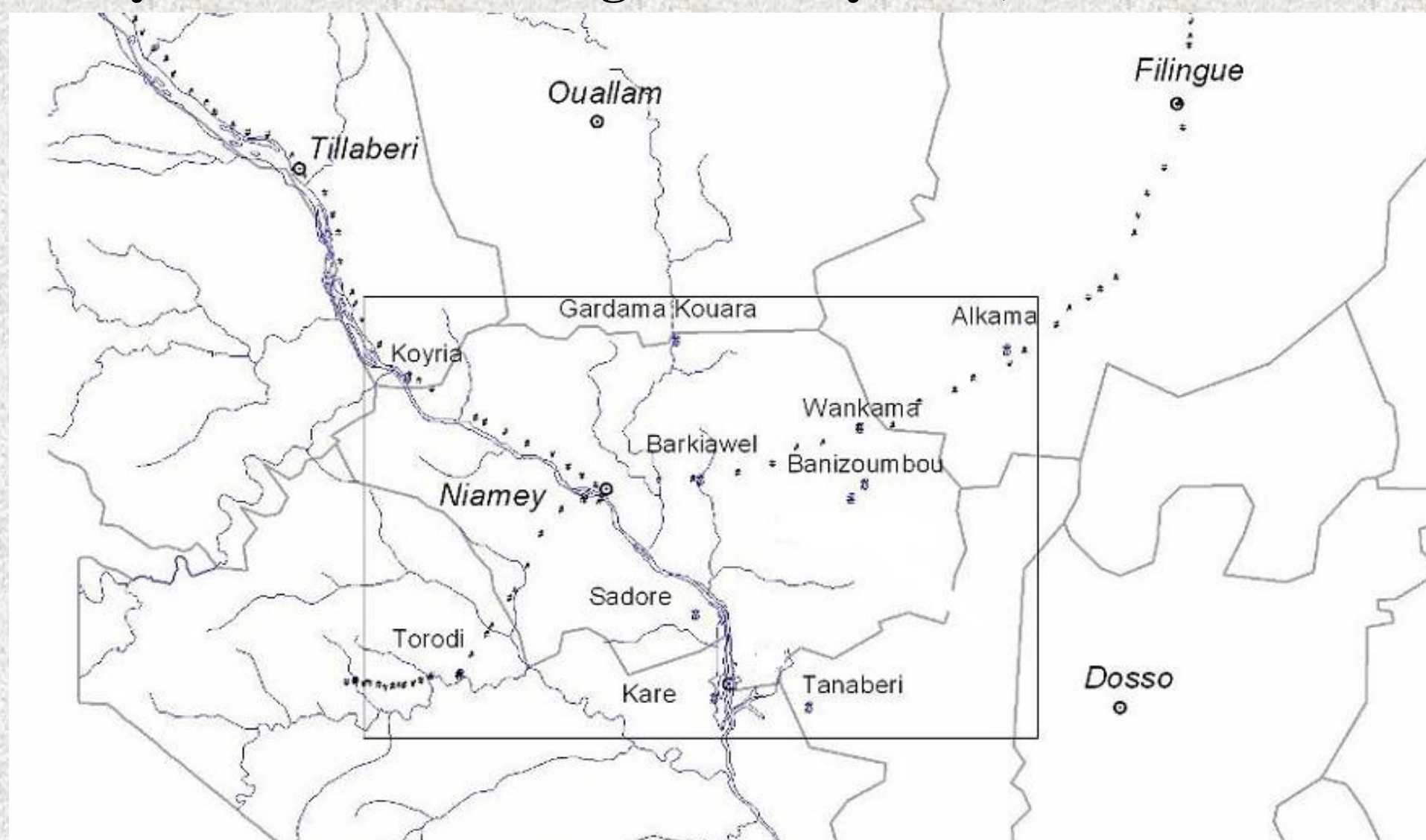


Figure 1 : Locations of on-farm survey sites within the Niamey squared-degree area



Results

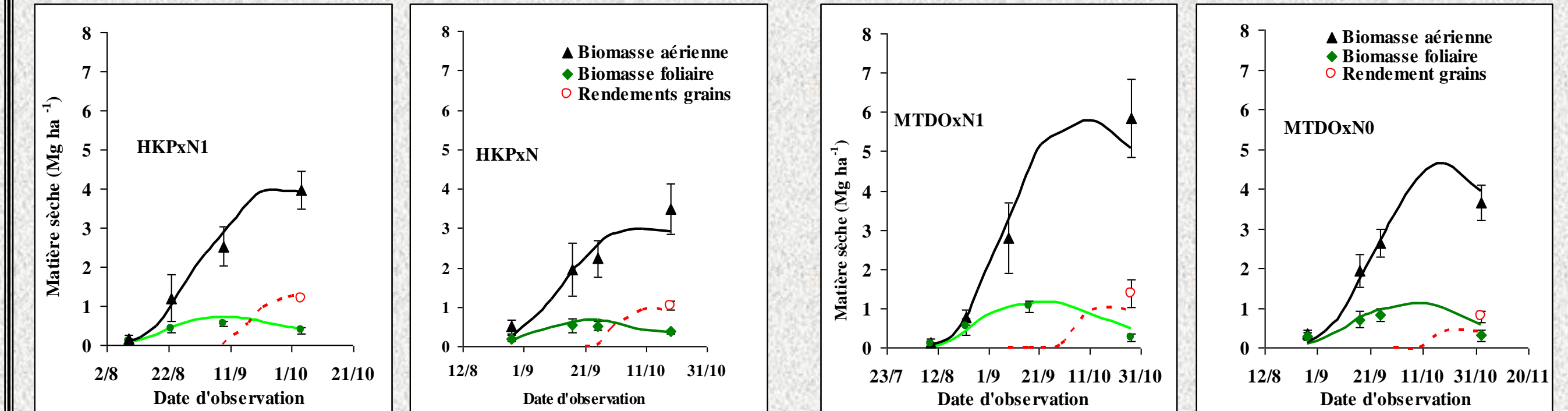


Figure 2 : Results of the adaptation of the SARRA-H model for two pearl millet varieties in Niger. AGRHYMET, 2002

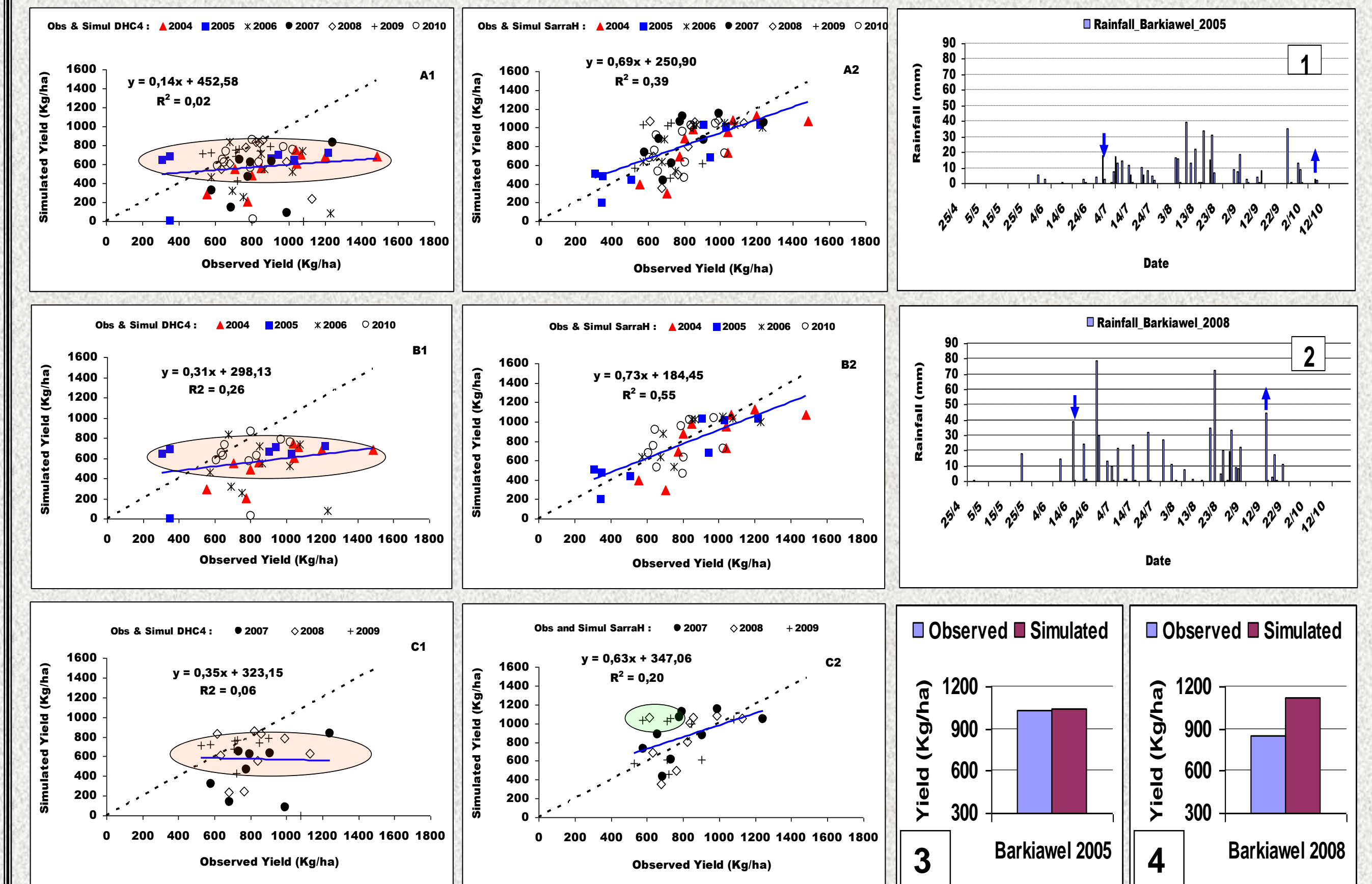


Figure 3 : Correlations between observed millet grain yields on farmers plots in the Niamey squared-degree area (years 2004 through 2010) and those simulated using the DHC4 (A₁, B₁ and C₁) and the SARRA-H (A₂, B₂ and C₂) models. Comparison between observed and SARRA-H simulated grain yields at Barkiawel for years 2005 and 2008 (3 and 4) in relation with rainfall distribution (1 and 2)

Discussion and Conclusions

The SARRA-H model was successfully adapted with the data collected on the 2002 and 2003 agronomic trials, as it could reproduce well the evolution of the above ground biomasses (leaves, stems, and grains) for the two millet varieties and the two nitrogen fertilization levels (Fig. 2).

When evaluated with on farm data, SARRA-H performed better than DHC4 for all years by giving higher correlation coefficients between simulated and observed grain yields (Fig. 3);

However, SARRA-H overestimated yields in some cases, namely when heavy rainfall events occurred shortly after crop emergence or at the flowering stage (Fig.3.2). Those events could trigger the washing away of the already insufficient soil nitrogen on the one hand, and of the flowers on the other hand, leading to low observed grain yields (Fig. 3. 4). Both of these phenomena are not accounted for by SARRA-H.

In the absence of very heavy downpours during the crop cycle though (Fig. 3.1), observed on-farm grain yields and those simulated by SARRA-H match very well (Fig. 3.3).

SARRA-H has the additional advantage of having been adapted for several crops (millet, sorghum, and maize) and of accounting for the photoperiod sensitivity of local varieties which are still widely used by West African smallholder farmers. It can therefore valuably replace the DHC model for famine early warning purposes, as well as climate change impact studies on crop yields in West Africa.

Objectives

- Improve the crop yield forecasting model used by the AGRHYMET Regional Center for famine early warning in West Africa.
- Evaluate the capabilities of the SARRA-H and DHC4 models to simulate actual millet yields, observed on-farm in the Niamey squared-degree area,

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