Possible *ex-ante* assessment of rice-vegetable systems performances when facing data scarcity: use of the PERSYST model in West Africa

Théo Furlan *[1,2], Rémy Ballot [3,4], Laurence Guichard [3,4] & Joël Huat [±2,5]

[1] Montpellier SupAgro, F-34060, Montpellier
[2] CIRAD, UPR HortSys, F-34398, Montpellier
[3] INRA, UMR 211 agronomie, F-78850, Thiverval-Grignon
[4] AgroParisTech, UMR 211 agronomie, F-78850, Thiverval-Grignon
[5] Africa Rice Center, 01 BP 2031, Cotonou, Benin
* Speaker
[±] Corresponding author: j.huat@cgiar.org

1 Introduction

Inland valleys (also called *bas-fonds*) are considered to be promising ecosystems for increasing food security in West Africa due to their relatively high and secure water availability and soil fertility compared to the surrounding uplands (Andriesse *et al.*, 1994). These areas amount to more than 22 million ha in West Africa and are of particular interest for the intensification of agricultural production, in order to feed the constantly increasing population (Rodenburg *et al.*, 2014). To achieve well-adapted inland valleys development, public and private decision-makers need accurate and reliable data on system productivity. In West Africa, agricultural yields are difficult to estimate on a large scale due to a lack of agricultural production records and crop management variability. Under such conditions, agricultural models could be a relevant option for viable yield estimation. In this study, we set out to adapt the PERSYST model (Guichard *et al.* 2013), developed by INRA in France for *ex-ante* assessment of cropping systems based on annual crops, for crop yield estimations in inland valley rice-vegetable systems under West African conditions.

2 Materials and Methods

The study was carried out in 5 *bas-fonds* in the departments of Mono and Couffo in southwestern Benin, and 2 *bas-fonds* in the Circle of Sikasso in southern Mali. In 2013 and 2014, we interviewed 49 farmers in Benin and 45 farmers in Mali, covering 160 and 94 fields, respectively, ranging from several acres to 1 ha. Data on household structure and functioning, as well as land use, crop rotation and cropping practices were recorded by technicians from extension services (public and NGO) and from research centers (Institute of Rural Economy in Mali). The field sizes were calculated by GPS tracking in both countries. In Mali, crop damage, weed pressure and harvested production were recorded on two or three observation plots per field to calculate yield. In Benin, harvesting was finished when the interviews began. Harvested yields were therefore estimated with farmers in local units. As these units varied in terms of weights, volumes and containers, we all measured them on the local markets to increase dataset reliability. Soil samples were taken at plot level (in Mali) or *bas-fonds* level (in Benin) for chemical and texture analysis, while taking into account farmers' knowledge about soil fertility. Focus groups were organized at village level to estimate inter-annual yield variability and identify the main factors affecting yields according to local farmers' knowledge. A literature review and interviews of scientific experts completed the datasets. Data collection, data checking, and analysis were performed by the scientific team using descriptive statistics and the PERSYST and DEXI models.
PERSYST is based on a participatory parameterization approach, integrating local expert knowledge. Crop yield calculations take into account crop rotation and crop management effects, allowing simulations at cropping system level. Crop management effects on yields were estimated by DEXi (Bohanec, 2008), a qualitative multi-criteria assessment tool integrated into the model.

3 Results – Discussions

The identified cropping systems mainly consisted of lowland rice during the rainy season followed by one or two vegetable crops during the dry season. In Benin, the main vegetable crops were two leafy vegetables 'crincrin' (*Corchorus olitorius*) and 'gboma' (*Solanum macrocarpon*), hot pepper (*Capsicum annuum*), and okra (*Abelmoschus esculentus*), while in Mali, potato (*Solanum tuberosum*) and sweet potato (*Ipomoea batatas*) remained the most cultivated crops.
We observed a great range between maximum and minimum yields within a cropping season (Table 1). Inter-annual yield variability was also high, with sometimes a ten-fold increase between bad and good years. According to the farmers, rainfall variability explained most of these differences. The availability of water was recorded as a main constraint. Farmers' knowledge about soil fertility matched the results of the laboratory analysis fairly well.
The GPS tool appeared to be very useful for accurate field size estimation. The field size sometimes changed between two rainy seasons. Indeed, after a rice crop, the field was split into several smaller plots for vegetable growing (Fig 1.)

and not in the same manner, thus making it difficult to clearly discern the effect of the previous crops on the following crops. Moreover, the person cultivating a field could also change from one year to the next. This practice casts doubt on the method of assessing the cropping system effect when the boundaries of the field change considerably from one cropping season to another. We also observed complex crop associations, mixing maize, cowpea and cassava, for example, and sowed on different dates.

Table 1. Estimated crop yields in Benin and Mali in 2013/2014

Country	Crop	Mean *(t.ha^{-1})*	Minimum *(t.ha^{-1})*	Maximum *(t.ha^{-1})*	Nb answers
Benin	Rice	2.6	1.1	4.6	21
	Crincrin	12.0	2.9	24.9	13
	Gboma	1.1	0.4	2.0	10
	Maize	2.3	0.5	6.4	14
	Cassava	4.7	3.8	5.5	2
	Hot pepper	1.6	0.4	3.3	14
Mali	Rice	1.3	0.2	4.5	Focus group
	Potato	19.5	5.3	29.9	71
	Sweet potato	12.5	10	15	Focus group
	Egg plant	2	0.7	4.0	Focus group
	Maize	0.9	0.5	1.5	Focus group

Fig. 1. Changes in land use at field level from one rainy season to the next. On the left: rice in the rainy season (year 1); in the middle: field divided for 5 vegetable crops; on the right: rice in the rainy season (year 2)

Use of the PERSYST model on African family farming systems was limited due to a lack of references and data, and a lack of knowledge and local expertise among farmers as well as among research and extension service technicians. To improve co-operation with farmers and the data collection process in terms of time saving and data accuracy and profitability, there is a need to effectively teach technicians and researchers about farming system complexity, the different reference frameworks used by farmers and scientists, and about erroneous results due to a choice of poor methods (Van Asten *et al.*, 2009). Poor quantitative information was found in the scientific literature concerning the effects of the nitrogen cycle, and of cropping systems and crop management operations on yields under local or similar soil and climate conditions. However, the credibility of the simulation model can be improved if the relevant agronomic improvements that can be promoted for smallholder farmers in West Africa can be precisely addressed (Whitbread *et al.*, 2010). By combining the research and farmer knowledge provided by the literature review and the different interviews (individual and collective), respectively, we were able to successfully parameterize the DEXi model for assessing the effect of different crop management scenarios on yield.

4 Conclusions

Although we could not fully use the PERSYST model due to a lack of scientific knowledge in the African environment, DEXi was used to estimate crop yields at field level. This study highlights key knowledge that remains to be acquired to capture the effect of cropping systems on the observed yield gaps in the context of African farming systems and land use management. Moreover, substantial investment in the training of observers and technicians from research centers, as well as extension agencies, is needed to really benefit more from smallholder farmers' knowledge as a way of increasing the use and relevance of model simulation.

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