Assessment of banana farmers' flexibility for adopting agro-ecological innovations in Guadeloupe: a typological approach

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Abstract: *As a response to a severe economic and environmental crisis facing banana production in Guadeloupe (French West Indies, FWI), different agro-ecological innovations such as improved fallowing and intercropping are being developed. As a contribution to this process, we characterized farmers' flexibility for adopting these innovations. Using a typological approach we characterize the diversity of the different banana management systems, their performance and their compatibility with farmers' decisional framework. Revealing these internal compatibilities we were able to assess the flexibility of the different farm types for adopting the innovations. Our results showed that flexibility may vary greatly, both among farm types for a given innovation, and among innovations for a given farm type. The results are then used for discussing the relevance of the innovations to different farming situations.*

Keywords: *farmer's flexibility, typology, innovative management system, banana, Guadeloupe*

Introduction

The banana crisis in the FWI and the alternative technical options

French West Indies production of bananas for export is facing a severe economic and environmental crisis due to market liberalization and the emergence of new environmental constraints such as pesticide regulations (Dulcire and Catan, 2002; Catan and Dulcire, 2003). The weak competitiveness of banana production in FWI at the global level is due to higher labour costs and the decrease in public subsidies following the liberalization of the European banana market. This weak competitiveness is reinforced by the technical practices of recent decades, based on monoculture, ploughing and intensive use of expensive chemical inputs, in particular to control the main pests of the banana crop such as the weevil *Cosmopolites sordidus* and the endoparasitic nematode *Radopholus similis*. These practices have led to yield loss (Clermont Dauphin, 2004), chronic lack of cash flow, and income erosion (Bonin, 2006). Combined with increasing social pressure for more environmentally-friendly practices and the prohibition of numerous biocides, this situation has led the farmers into an economic and technical crisis. As a result of this crisis the number of banana farmers has decreased drastically during the last thirteen years (see figure 1). This drastic decrease threatens the local economy, as banana exports used to be an important source of income and employment for these islands, where the unemployment rate is over 25% and the trade balance is badly in deficit (INSEE, 2001).

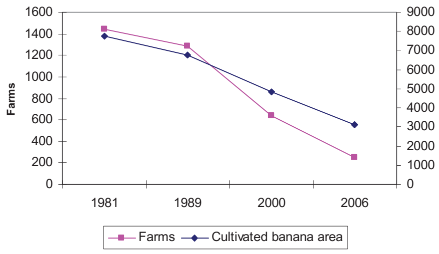

Figure 1. Evolution of total banana farms number and total cultivated banana area in Guadeloupe since 1981.

Current banana management systems therefore need to be adapted to this new situation. However farmers' flexibility at a strategic level is small, as the persistent contamination of soils by chemicals reduces the scope for diversification. On the other hand, the insularity and the weak structure of other sectors makes access to new markets difficult. To help farmers to adapt their management system to this new situation, agronomic research and technical institutions are currently focussing on different technical alternatives that would allow the use of chemical inputs to be reduced while maintaining or increasing yields. The first is to introduce rotations or improved fallows into the banana cropping system to reduce parasitic pressure and consequently reduce the use of nematicides and insecticides

(Chabrier and Quenehervé, 2003). Possible crops for inclusion in the rotation would be C*rotalaria juncea* and *Brachiaria decumbens*. The second technical innovation is intercropping with a cover crop that would be intercropped with the bananas. These crops could control weeds as an alternative to herbicides, and possibly be used as green manure if leguminous. Candidate species for intercropping are C*anavalia ensiformis,* an annual leguminous crop, and two perennial crops, *Brachiaria decumbens* and *Impatiens sp*.

Questions, theoretical background and objectives of the paper

The above-mentioned agro-ecological innovations could be suitable options for improving the sustainability of banana production in Guadeloupe. However farmers often fail to follow the advice put out by the extension services, and do not always adopt technical innovations (Aubry *et al.*, 1998; Renaud *et al.* 1998; Orr and Ritchie 2004; Bonin, 2006). This could be explained by the existence of a set of strategic and functional constraints to farmers' actions that could render some innovations impractical. This suggests that it may be worth studying farmers' flexibility as regards the adoption of agro-ecological/technical innovations. Flexibility could be defined as the capacity to innovate in the banana technical management system of without endangering the farming system's at another levels. This kind of study requires quite a lot of research into farming systems, and it is now assumed that in order to design new agronomic techniques it is crucial to evaluate the capacity of farmers to adopt them. The constraints to farmers adopting an innovation in one of their crop management systems could be revealed by assessing the decision-making process that drives their current practices, and most particularly the practices that might be affected by the adoption of the new techniques (Sebillote and Soler, 1990; Papy, 2001).

Crop management systems need to be characterized because of the internal logic of agricultural systems (Osty et al., 1998; Meynard et al., 2001). Figure 2 gives a simplified representation of this logic, showing that the farming system and its sub-components are consistent with the decisional framework of the farmer and the performance of the system. At a functional level the assessment of one given technique independently from the others is impossible, because farmers can have limited flexibility, like limited or unsuitable production factors (e.g. land and labour) for daily or weekly action at the whole farm level, and so may have to prioritise the allocation of their resources among different operations or different crops. On the other hand farmer's decisions are interdependent because they are driven by a number of fixed projects at a strategic level. So to identify the overall coherence of a banana management system we need to place it within a systemic and functional description of farm operations under the decision-making process of the farmer. The farmer's cognitive action model developed by Sebillotte and Soler (1988) provides a suitable framework to characterize flexibility and has been used in many studies (Aubry et al., 1998; Dounias et al., 2002; Duru and Hubert, 2003; Ducrot and Capillon 2004; Joannon, Papy et al. 2005; Cournut and Dedieu, 2005; Dedieu et al., 2006; Navarrete et al., 2006).

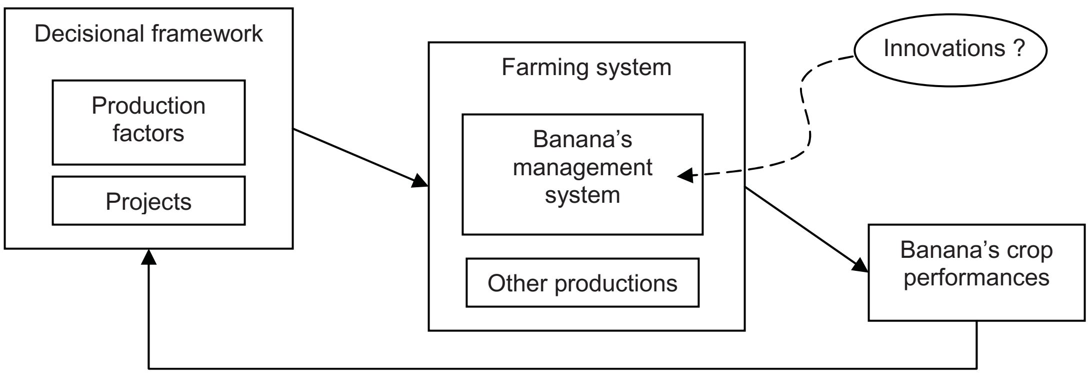

Figure 2. Conceptual representation of the banana management system under the control of the farmer's decisional framework for a system approach to innovation adoption.
NB: The unbroken arrows mean "under control"

Table 1. Description of the variables used in the study

	Variables	Definitions	Units
Decisional framework	ALTI	Mean altitude of the farm	m
	AGE	Age of the farmer	year
	SAU	Total utilised agricultural area	ha
	MEC	% of the SAU which is suited to mechanical ploughing	%
	PEN	Average slope of the fields of the farm	%
	IRRI	% of the SAU which has access to irrigation	%
	NEX	Number of farms owned by the farmer	units
	CJMO	Average cost of a day's work on the farm	€ day^{-1}
	UTHf	% of family workers	%
	UTHt	% of total work done by temporary workers	%
	SOL	Type of soil : andisol, ferralitic, or nitisol	-
	FONC	Dummy variable : equals 1 if total land tenancy; otherwise 0	-
	FRAC	Dummy variable : equals 1 if farmer's land is subdivided; otherwise 0	-
	REVEX	Dummy variable : equals 1 if farmer has external income 0 otherwise	-
	TRES	Dummy variable : equals 0 if the farmer is cash-flow limited; otherwise 1	-
	INV	Dummy variable : equals 1 if farmer has investment capacity; otherwise 0	-
	ETU	Dummy variable : equals 0 if no training, 1 if agricultural training, 2 if higher studies	-
	INFO	Dummy variable : equals 0 if no contact with extension agents, 1 if contact with extension agent, 2 if contact with local agricultural research centre	-
	STADE	Farmer project for the strategic guidance of his farm : establishment, stabilization, diversification, or abandonment	-
Farming system	%SAUb	% of SAU cultivated with bananas	%
	DIVERS	% of agricultural income from crops other than banana	%
Banana's management system	REPLANT	% of bananas area replanted each year	%
	VP	% of seedlings which are produced by tissue culture and nematode-free	%
	Q-fert	Nitrogen applied per plant at one pass	g
	FRE-fert	Number of nitrogen applications each year	units
	HERBI	Number of herbicide treatments per year	units
	NEMAT	Number of nematicide treatments per year	units
	RECC	% of banana plants replaced each year	%
	SOINS	Amount of post-flowering work to bunches for banana quality management	days $ha^{-1} year^{-1}$
	HAUB	% of anchored flowered plant for down beating limitations (using guy ropes)	%
	FRE-EMB	Number of harvest and packaging operations per year	units
	DESTRUC	Type of destruction of banana fields before replanting : mechanized, chemical, or manual	-
	Wsol	Type of tillage : mechanized or manual	-
	ROT	Dummy variable : equals 1 if fallow or rotations present in banana annual rotation; otherwise 0	-
	ANA-NEM	Dummy variable : equals 1 if nematode monitoring through root analysis; otherwise 0	-
Banana's crop performances	CYC	Cycle duration in months	month
	I-ENV	Biocides applied each year	kg
	EFF-EMB	Work efficiency of packaging chain expressed in boxes per workday	boxes day^{-1}
	%MUR	% of banana losses during export chain due to early maturation	%
	R	Average yield of banana fields	t $ha^{-1} year^{-1}$
	C/R	Weight of bunch indicator (average number of 18.5 kg boxes filled with one bunch)	boxes $bunch^{-1}$
	TRI	percentage of rejected bananas	%
	Q	Quality : average return from bananas according to their quality	€ kg^{-1}
	BMO	Work demand	days $ha^{-1} year^{-1}$
	CP	Amount of production costs	€ $ha^{-1} y^{-1}$
	MN	Banana gross margin	€ $ha^{-1} y^{-1}$

In our case, the technical options suggested for improving the sustainability of banana management systems in Guadeloupe concern different decision levels and could affect different points in the management system on different spatial and time scales. For example, the introduction of new rotations or improved fallow will modify over the short term the total cultivated banana area that is productive. This will induce a temporary decrease in banana production and thus in the farmer's income and labour requirement. But later it could increase the labour requirement by increasing production. Furthermore, the adoption of this technique will affect both the performance of the system and other technical decision rules, like the choice of cropping pattern and land allocation to crops, strategy of nematicide treatment, and introduction of a sequence of operations for managing the rotation or the fallow. As for the intercropping technique, it will introduce new operations into the farm like seed sowing between the banana rows, and cover crop pruning. The adoption of intercropping will bring an end to herbicide treatment and slow down field operations by making access to the banana plants more difficult. As a lot of decision rules and parameters of the banana management system could be affected by the adoption of the innovative techniques, it was necessary in our case to characterize and understand the decision-making process of the whole banana management system.

Due to the existence of various topographic situations - uplands and lowlands, where soils, slopes, climate, and the possibility of tractor ploughing varies considerably – and the complexity of the agrarian history in Guadeloupe – potentially responsible for variability in production factors such as land and workforce – we assumed the existence of a great diversity of banana management systems. The spatial variability of banana management systems and farm situations has to be assessed for correctly assessing the existing flexibility and to allow it to be compared from farm to farm. Typology building is an appropriate tool for such a characterization. Through type elaboration, it allows us to characterize and order complex systems such as agricultural systems. The result of this procedure is a system of types (farm typology for example). As Landais (1998) said, most developed typologies mainly concern the nature of the farming system and are aimed at i) facilitating advisory work ii) identifying farming changes iii) exploring the responses of farm diversity to a structural change (price changes, subsidies, regulations, emergence of an innovation). Here we choose to use typology for farm diversity modelling with Landais's third aim, with the objective of confronting it with possible innovations. So the question that we try to address in this study is "Do the farmers have sufficient flexibility for adopting the innovations and are these innovations possible for every farmer?". The objective of this paper is to present our study aimed at i) characterizing the diversity of banana management systems and identifying their consistencies with farming situations by using a typological approach and ii) using the assessment of these situations and their consistencies for identifying flexibility in adopting innovations.

Materials and methods

Sampling and questionnaire design

The method is based on 66 interviews with banana farmers selected randomly from the whole population after a stratification of the population according to soil types and farm size. These two factors were used to provide a good representation of the diversity of the economic, soil and climatic conditions of Guadeloupe. The sample selected represents about ten percent of the whole population. Each farm survey lasted about 3–5 hours, spread over two visits. The interview was divided into four parts allowing a general description of the decision-making process for the choice of the banana management system. The variables used for describing a farmer's decision-making process for his banana management system were (i) a description of his decisional framework in terms of production factors and projects, (ii) the nature of the farming system, (iii) a description of the banana management system through the explanation of each decision rule in the technical management, and (iv) the agronomic, technical, and economic performance of the system. Some variables were calculated after the survey. An exhaustive presentation of the 33 qualitative and 12 qualitative variables used in the study is given the table 1. The high coefficients of variation of these variables in the sample (see table 2) illustrates the wide variability present.

Table 2. Distribution of the quantitative variables in the sample population

	Minimum	Median	Maximum	Mean	Coefficient of variation
ALTI	10	190	650	221	73%
AGE	24	50	78	50	22%
SAU	1	10	260	24	156%
MEC	0%	98%	100%	66%	61%
PEN	0	1	3	1	86%
IRRI	0%	0%	100%	18%	212%
NEX	1	1	7	1	70%
CJMO	19.8	50.3	71.5	48.2	26%
UTHf	0%	33%	100%	40%	79%
UTHt	0%	10%	56%	14%	112%
%SAUb	26%	80%	100%	74%	31%
DIVERS	0	1	4	2	98%
REPLANT	0%	14%	31%	13%	60%
VP	0%	50%	100%	49%	93%
Q-fert	0	100	500	109	59%
FRE-fert	2	10	18	10	50%
HERBI	0.0	4.9	12.0	5.6	60%
NEMAT	0.0	1.0	4.0	1.3	84%
RECC	0%	11%	35%	11%	71%
SOINS	16	37	91	40	43%
HAUB	0%	75%	100%	65%	56%
FRE-EMB	26	52	52	44	25%
CYC	7	9	14	10	17%
I-ENV	0	10	25	11	57%
EFF-EMB	6	21	57	22	50%
%MUR	0%	2%	15%	2%	136%
R	5	25	59	27	43%
C/R	1	1	2	1	23%
TRI	1%	10%	30%	12%	65%
Q	0.000	0.535	0.611	0.511	19%
BMO	63	141	240	140	28%
CP	6110	18731	36158	19897	32%
MN	-4816	2346	15919	2862	176%

Statistical treatments for typology elaboration and validation

The method used is based on a combination of statistical treatments presented in figure 3. It is a three-step process. The first step is to transform the quantitative variables into new quantitative non-correlated variables by Principal Component Analysis (PCA). The advantage of this preliminary treatment is that it allows us to remove statistical noise from the data by taking into account only the first components of the PCA. We then used an algorithm of Agglomerative Hierarchical Clustering (AHC) for the grouping of individuals into specific farm types using the principal components of the PCA. This method consists of progressively grouping individuals according to their resemblance, measured through an index of dissimilarity. The index used in the study was the Euclidian distance (D). The algorithm then groups individuals into pairs by selecting the individuals whose D is minimum at each step. The pairs thus obtained are then aggregated with the "inertia augmentation" method (Ward, 1963). This consists of aggregating groups by minimizing the augmentation of the total intra-class inertia. The advantage of this method is that it allows very homogenous classes to be obtained.

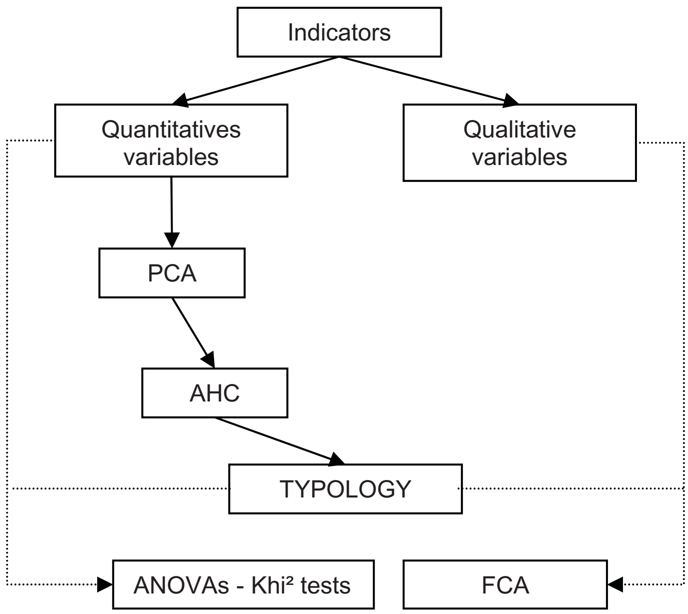

Figure 3: statistical process used for typology elaboration and validation.
→ : Typology's building
⇢ : Typology's validation

The validity of the typology is then tested in step two. First we made a Correspondence Analysis (CA) performed with the qualitative variables which revealed how the system of types obtained agrees with the correlation structure of the qualitative variables. Then we made an Analysis of Variance (ANOVA) and Khi² tests to see which variables were significantly correlated with membership of the types. This treatment allowed us to avoid in the analysis the comparison of variables that are not significantly correlated with types. The characterization of the farm types in terms of decisional framework, banana management system and performance was then made by selecting the mean or modal value of each variable. All the statistical calculations were performed with the software XLSTAT-Pro 5.1 version 4 (Copyright © Addinsoft 1995 – 2002). The statistical treatments were made and are presented according to the recommendations of Webster (2001).

Results

The farm typology

The PCA reduced the number of dimensions in the data by selecting the first eleven components of the PCA which explain 77% of the total variability (see table 3). The analysis of the contribution of the initial variables to the first two components of the PCA illustrates two main trends in the data (see figure 4). The first component shows a correlation between the total usable area of the farm (SAU), the access to irrigation (IRRI), the number of farms owned by the farmer (NEX), intensive practices (I-ENV and REPLANT) and good agronomic and economic performance (MN, R, FRE-EMB). On the other hand, the labour cost seems to be on average lower on small farms, due to the presence of a large family workforce (compare UTHf and CJMO). This axis represents good economic flexibility, intensive practices and good performance that are correlated with farm size. The second axis discriminates the lowlands and the uplands, as it opposes the variables ALTI and MEC, i.e.

Factor	Corresponding Eigen value	Cumulated % of variance
F1	6.748	20%
F2	3.801	32%
F3	2.849	41%
F4	2.093	47%
F5	1.885	53%
F6	1.497	57%
F7	1.418	61%
F8	1.356	66%
F9	1.309	70%
F10	1.180	73%
F11	1.126	77%

Table 3. Eigen values and cumulated % of variance corresponding to the 11 principals factors of the PCA.

the possibility of tractor ploughing.

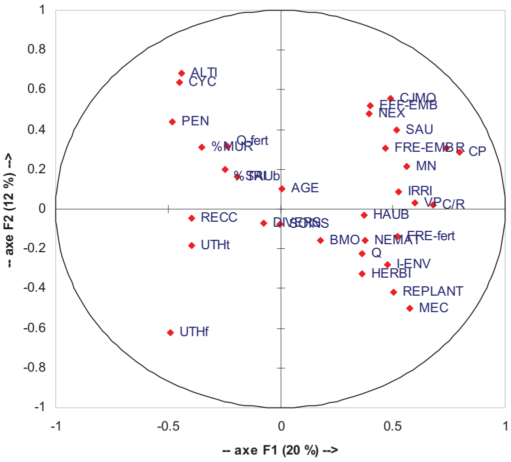

Figure 4. Representations of the variables used in the study in the correlation circle in the plan of the two first factors af the PCA.

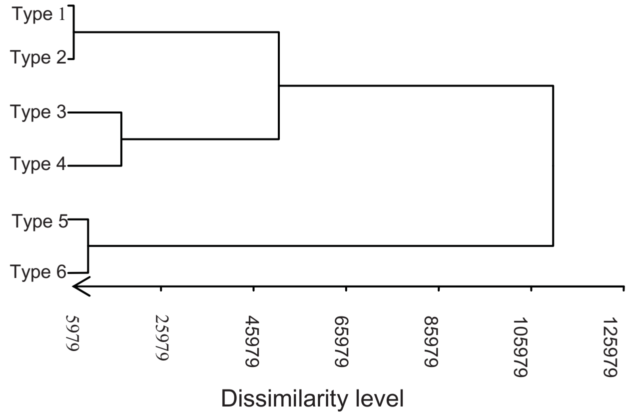

Figure 5. Dendrogram obtained after a 6 classes truncation in the classification algorithm and evolution of the global dissimilarity.

Trial and error tests permit us to finally retain a 6 class truncation in the AHC algorithm which allows us to reduce the overall dissimilarity level (see figure 5). The 6 class truncation was the most satisfactory in terms of inter-group dissimilarity and intra-group homogeneity. However we could see some similarity between types 1 and 2, 3 and 4, and 5 and 6. For this reason these types, although different, should have some common characteristics.

	Number of farms	Fraction of population	Fraction of banana area
Type 1	9	14%	4%
Type 2	21	32%	14%
Type 3	4	6%	30%
Type 4	19	28%	44%
Type 5	4	6%	5%
Type 6	9	14%	3%

Table 4. Structure of the typology

The distribution of the different farm types reveals clear differences in farm area among types (table 4). Type 3 represents only 6% of the population but has 30% of the banana area. Conversely types 1 and 2 represent almost 50% of the population but only 18% of the area. Type 5 is a minority type with only about 5% of the population and 5% of the total banana area.

This typology is validated by applying it to a CA with the qualitative variables (figure 6). Axis 1 opposes farms that are limited by cash flow, have poor access to information and practice manual replanting. Axis 2 represents low land tenancy. The results of this analysis show that groups are well discriminated in the plane of the two first components and their relative position is exactly the same as in the dendrogram. This means that the correlation structure of the qualitative variables could discriminate different farm types well. Although it is not a proof of the validity of the typology *per se*, it shows that the typology elaborated from the quantitative variables agrees with the distribution of the qualitative ones. ANOVA

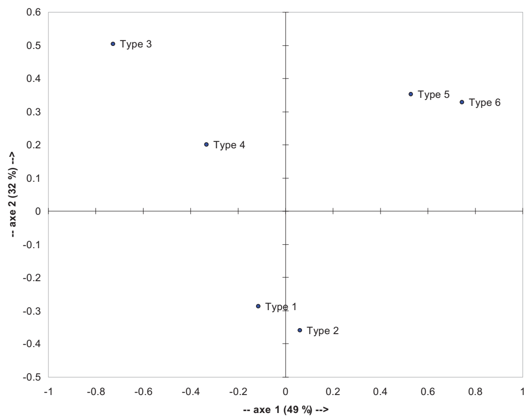

Figure 6. Representation of the farm types in the plan of the two principal factors of CA.

of quantitative variables showed that only four of the thirty variables were not significantly correlated with membership of the type. These are AGE, DIVERS, TRI and Q. This means that the variability of these variables among types could not be taken into account in interpreting the typology. The others were very significantly correlated with farm type membership.

Main characteristics and coherences of each type

Nature of banana management systems

Characteristics of the banana management system of each farm type are presented in table 5. We can see two main levels of differentiation among types which generate three main types of banana management system. Type 5 and 6 are characterised by perennial management with no replanting and very little anchorage of banana plants, which differs from all other types that are replanting their fields every 5 to 8 years. However types 1 and 2 differ from types 3 and 4 as they do not practise any rotation, and these last ones always use tissue culture plants for replanting and banana anchorage after flowering. Type 3 is the most intensive, with 17 applications of fertilizer and 2 - 4 nematicide treatments each year. By contrast, type 5 is very extensive with manual weeding, no nematicide treatment, and only 3 chemical fertilizer treatments per year. Types 1, 5 and 6 harvest less than 52 times per year. They display no great difference between types in terms of quantity of work for quality control, which shows that it may be a priority operation for all farmers.

Table 5. Characteristics of the different farm types as regards banana's current technical management expressed by the mean or mode of the variables in each type.

Banana management system	TYPE 1	TYPE 2	TYPE 3	TYPE 4	TYPE 5	TYPE 6
REPLANT	21%	15%	15%	16%	0%	0%
VP	50%	40%	100%	90%	0%	0%
Q-fert (g/plant)	100	100	105	100	205	100
FRE-fert	12	9	17	12	3	6
HERBI	4.8	6	5	6	0	4
NEMAT	1	1.5	2.5	1	0	1
RECC	11%	11%	9%	5%	12%	15%
SOINS	47	32	44	38	32	43
HAUB	50%	80%	100%	100%	15%	7%
FRE-EMB	39	52	52	52	39	31
DESTRUC	mechanical	mechanical	mechanical	chemical	0	0
Wsol	mechanical	mechanical	mechanical	mechanical	manual	manual
ROT	0	0	1	1	0	0
ANA-NEM	1	0	1	1	0	0

Decisional framework

Table 6 shows that all the farm types are very specialised in banana production as they all have more than 60% of their cropping area under bananas. This may be because banana production requires a certain level of equipment, in particular for packaging the fruit. Types 1, 2, 5 and 6 are small farms, whereas type 4 and particularly type 3 have plenty of land. This could explain why types 1, 5 and 6 each harvest less than 52 times per year, as they don't have enough fruit each week to fill a container. Types 5 and 6 are characterized by their location high in the mountains where the slope is steep (30 to 40%). By contrast, the other types are located at the foot of the mountains on ferralitic or nitic soils in an area where mechanization is possible. Mechanization is important as replanting operations are very costly in terms of labour. This could explain why, due to this possibility, they practise regular replanting and why they are mostly utilizing purchased plants for replanting. Types 3 and 4 are characterized by no cash flow limitations and better access to information and investment capacities. They differ from the others in the nature of their workers, who are all full-time employed and better paid. The low cost of labour in types 1, 2, 5 and 6 could be explained by the family nature of their workers. This low labour cost of labour may explain why these systems survive despite financial limitations.

Table 6. Characteristics of the different farm type as concerns the farming system and the decisional framework.

Decisional framework and farming system	TYPE 1	TYPE 2	TYPE 3	TYPE 4	TYPE 5	TYPE 6
%SAUb	71%	83%	82%	64%	95%	95%
ALTI	80	115	123	250	550	380
SAU	4	10	82	28	8	6
MEC	100%	100%	100%	75%	0%	0%
PEN	10%	0%	10%	10%	20%	30%
IRRI	0%	0%	100%	0%	0%	0%
NEX	1	1	3	1	1	1
CJMO	33	46	61	57	41	38
UTHf	74%	42%	2%	9%	37%	70%
UTHt	12%	15%	0%	0%	45%	14%
SOL	nitisol	ferralitic	nitisol	andisol	andisol	andisol
FONC	1	0	1	1	1	1
FRAC	0	1	0	0	0	0
REVEX	0	0	1	1	1	0
TRES	0	0	1	1	0	0
INV	0	0	1	1	0	0
ETU	0	1	2	1	2	0
INFO	0	0	2	2	0	0
STADE	diversification	diversification	stabilization	stabilization	abandonment	establishment

Banana crop performance

Table 7 shows that yields of types 1, 2, 4 and 6 are all below 25 t ha^{-1} $year^{-1}$, which is very low compared to the potential yield of bananas, which is about 50 to 60 t ha^{-1} $year^{-1}$ in Guadeloupe. The low yields can be explained by high disease levels due to the practice of monoculture. Regular replanting may be important for maintaining a good plant density, but it is difficult for type 6 and particularly for type 5 because of their location in the uplands. Furthermore cycle duration is negatively correlated with altitude, whereas bunch weight and percentage of mature fruits are not significantly influenced by it. For type 5 the relatively low level of fertilization due to strong financial limitations could be another reason for the low yields. Type 3 is the most productive and economically efficient. The other farm types have very low net income levels, and this is the cause of the drastic reduction of the number of banana farms during last fifteen years. There is a strong correlation between yield and net income, which shows that as a general rule the production model in Guadeloupe requires high yields. Production costs are high on every farm due to the high labour requirement for banana production and packaging which is at least 0,35 full-time work units per hectare. Environmental impacts range from 0 (for type 5) to more than 15 kg per hectare of active chemical substances each year. Type 3 and 4 are highly efficient at packaging, which could be explained by a high level of equipment and the benefits of scale.

Table 7. Characteristics of the different farm types as regards the banana management system's performance.

Banana management system performance		TYPE 1	TYPE 2	TYPE 3	TYPE 4	TYPE 5	TYPE 6
Environmental	I-ENV	7.5	15.5	17.5	10.2	0.0	8.4
Agronomic	R	21.4	22.5	45.2	38.5	17.3	18.6
	C/R	0.85	1.00	1.25	1.20	0.70	0.81
	CYC	9.0	9.0	8.0	10.0	12.0	11.0
	%MUR	1.0%	1.0%	2.0%	1.0%	4.5%	2.0%
Technical	BMO	162.2	128.3	139.6	156.5	84.0	122.6
	EFF-EMB	13.9	18.2	38.3	25.2	21.8	16.9
Economic	CP	16 329	18 469	29 597	25 648	13 349	14 807
	MN	499	885	9 676	5 654	-813	-404

Discussion : scope for adopting innovations and consequences for the innovation process

Type 3 represents only 6% of the total population but it represents 30% of the banana cultivation area. It is important for us to target it because, even though economically efficient, it may be harmful to the environment. Although it already includes rotations (principally with sugar cane), the problem is that they are still applying frequent nematicide treatments even though they appear to be unnecessary. A risk-averse attitude and the low price of nematicide treatment could explain this situation. This is one of the main differences from type 4, which is an adaptation of type 3, largely due to the possible existence of financial constraints at certain times of year. For types 3 and 4, innovation should be aimed at weed control by intercropping. Theses types have high financial flexibility and certain living cover crops could allow this objective to be fulfilled. But as the labour is essentially full-time employed and socially well structured, the arduousness of the work involved could be critical for the adoption by this practice, whose acceptance by the workers could be socially problematic. This remark is particularly pertinent for type 3, which are almost industrial plantations with up to two hundred employees working on the farm. Intercropping with *Brachiaria decumbens* could be a suitable innovation because the pruning of this herbaceous cover crop could be mechanized.

For types 1, 2, 5 and 6 the main problem is the low net margin due to low yields. This confers them low financial flexibility. Adoption of rotations seems to be problematic for these types. Type 5 and 6 have very limited scope for adopting rotations because they have steep slopes that make replanting very difficult. Rotations seem not to be feasible and specific replanting systems suited to the steep terrain should be devised for this type. For type 1 the limitation that could hinder the adoption of rotation or fallow seems to be shortage of land, as the adoption of rotation could cause a temporary fall in income which could threaten these mainly family farms. Short-lived improved fallows like *Crotalaria juncea* or rotation with a pineapple cash crop could be a suitable innovation for this type. However, all the innovations proposed could be of interest for this type, which is financially very limited but quite flexible as regards work reorganisation. The workforce is mainly family-based and can be reinforced by temporary workers or other farmers' help if necessary. This gives this system flexibility in managing a decrease or increase in workload during and after the adoption of rotation or fallow. Also, the arduousness of the work might be more easily accepted.

We should however point out that type 1 and 2 farms are in the lowlands where low rainfall and limited access to irrigation could become a problem if intercropped cover crops should compete with the bananas for water. *Canavalia ensiformis* could be useful for these farm types as it has a more extensive root system than banana and could colonize a deeper soil layer. For type 5 the most suitable innovative cover crop also seems to be *Canavalia ensiformis,* which, being leguminous, can substitute for fertiliser nitrogen on farms where this is not affordable. For type 6, *Impatiens sp* could be suitable, as it has low labour requirements.

Conclusion

Using a typological and a functional approach to the diversity of banana management systems we assess their main characteristics and internal logic. This allowed us to evaluate farmers' flexibility to adopt different possible innovations, and thus the potential for adoption of each innovation for each kind of farmer. Some farmers seem to be insufficiently flexible to adopt certain innovations. This needs to be borne in mind early in the process of prototyping and assessing innovations. This would ensure a better match of the innovations to the farming situations in Guadeloupe, and thus their likelihood of adoption.

References

Aubry, C., Papy, F., Capillon, A., 1998. Modelling decision-making processes for annual crop management. *Agricultural Systems* 56, 1, 45-65.

Bellon, S., Lescourret, F. , Calmet, J.P., 2001. Characterisation of apple orchard management systems in a French Mediterranean Vulnerable Zone. *Agronomie*, 21,3.

Bonin, M., Cattan P., 2006. Convergences and differences between the objectives of the financial support facilities and those of the farmers: the case of fallow periods in banana production of Guadeloupe. *Fruits*, 2006, 61, 9–23.

Capillon, 1993. *Typologie des exploitations agricoles, contributions à l'étude régionale des problèmes techniques.* PhD thesis, INA P-G, Paris.

Cattan, P., Dulcire, M., 2003. Quelles cohabitations de la banane et des autres activités territoriales ? Recherche-action dans le croissant bananier Guadeloupéen, in *Proceedings Organisation spatiale et gestion des ressources et des territoires ruraux*., 25-27, Montpellier, France, February 2003.

Chabrier, C. and P. Queneherve (2003). Control of the burrowing nematode (Radopholus similis Cobb) on banana: impact of the banana field destruction method on the efficiency of the following fallow. *Crop Protection* 22, 1, 121-127.

Clermont-Dauphin, C., Cabidoche, YM., Meynard, JM., 2004. Effects of intensive monocropping of bananas on properties of volcanic soils in the uplands of the French West Indies. *Soil Use and Management*, 20, 105-113.

Cournut, S. and Dedieu B., 2005. Simplification des conduites d'élevage en bovins laitiers. *Cahiers Agricultures*, 14, 6, 541-547.

Dedieu B., Servière G., Madeldrieux S., Dobremez, L., Cournut, S., 2006. Comment appréhender conjointement les changements techniques et les changements du travail en élevage ? *Cahiers Agricultures*,15, 6, 506-513.

Dounias, I., Aubry, C., and Capillon, A. (2002). Decision-making processes for crop management on African farms. Modelling from a case study of cotton crops in Northern Cameroon. *Agricultural Systems*, 73, 3.

Dulcire M., Cattan P., 2002. Monoculture d'exportation et développement agricole durable : cas de la banane en Guadeloupe. *Cahiers Agricultures*, 11, 313-321

Duru, M., and Hubert, B., 2003. Management of grazing systems: from decision and biophysical models to principles for action. *Agronomie*, 23, 689-703.

INSEE, 2001. *Tableaux Economiques de la Guadeloupe.* Pointe à Pitre.

Landais, E., Deffontaines, J.P., Benoit, M., 1988. Les pratiques des agriculteurs : point de vue sur un courant nouveau de la recherche agronomique. *Etudes Rurales*, 109.

Landais, E., 1998. Modelling farm diversity. New approaches in typology building in France. *Agricultural Systems*, 58, 4.

Meynard, J.M., Doré, T., 2001. L'évaluation et la conception de systèmes de culture pour une agriculture durable. *Compte rendus de l'Académie d'Agriculture Française*, 87 , 223-236.

Navarrete, M., Le Bail, M. , Papy, F., Bressoud, F., Tordjman, S., 2006. Combining leeway on farm and supply basin scales to promote technical innovations in lettuce production. *Agronomy for Sustainable Development*, 26, 1, 77-87.

Orr, A. and J. M. Ritchie (2004). Learning from failure: smallholder farming systems and IPM in Malawi. *Agricultural Systems*, 79, 1, 31-54.

Osty P.L., Lardon S., De Sainte-Marie C., 1998. Comment analyser les transformations de l'activité productrice des agriculteurs ? Propositions à partir des systèmes techniques de production. *Etude Recherche Systèmes Agraires Développement*, 31, 397-413.

Papy, F., 2001. Interdépendance des systèmes de culture dans l'exploitation In Repères (Eds), *Modélisation des agroécosystèmes et aide a la décision*, INRA-CIRAD, 51-73.

Perrot, C., 1991. *Un système d'information construit à dire d'expert pour le conseil technico-économique aux éleveurs de bovins*. PhD thesis, INA P-G, INRA SAD/Institut de l'élevage, Paris.

Renaud, F., H. D. Bechstedt, 1998. Farming systems and soil-conservation practices in a study area of Northern Thailand. *Mountain Research and Development*,18, 4.

Sebillotte M., Soler, L.G., 1988. Le concept de modèle général et la compréhension du comportement de l'agriculteur, *Compte rendus de l'Académie d'Agriculture Française*, 59–70.

Sebillote, M. and L.-G. Soler, 1990. *Les processus de décision des agriculteurs (I).* Actes du séminaire du département SAD, Saint-Maximim, 2-3 mars 1989.: p. 93-118.

Ward, J.H., 1963. Hierarchical grouping to optimize an objective function. *Journal of the American Statistical Association*, 58 : 238-244.

Webster R., 2001. Statistics to support soil research and their presentation. *European journal of soil science*, 52, 331-340.