Reconstituting family transitions of Sahelian western Niger 1950-2000 : an agent-based modelling approach in a low data context

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Introduction

1 Among all of the gaps that stand between social science results and development operators' guidelines regarding rural areas in West Africa, that of the perceptions of the family structure has a crucial influence on the future evolutions of these societies and on the connection between development operators and the rural areas in which they work. This gap has both a historical and a sociological origin.

2 As discussed by Rain (1999) and Olivier de Sardan (2003), the enlarged and patriarchal family archetype was ultra-dominant in the beginning of the 20th century; however, this archetype is not inherent to the African tradition. Rather, it emerged from the need for strong clans and links due to the generalised insecurity and several epizooties and famines that affected Western Niger in the 19th century until the *Pax Francia* (Ki-Zerbo 1972; Gado 1993; Olivier de Sardan 2003). The colonisation era, with the opening of free land (thanks to the new security), the "indigenous code" and the military service, was a period of strong incentive for new settlements[1] as well as for the expansion of the existing multi-rationality, multi-activity and multi-finality within families[2] (Raynaut *et al.* 1997). In the post-colonisation era, with the demographic explosion and improvement in transportation, new economic activities such as seasonal migration arose, seasonal gardening was eased and farming colonisation began in the territory. The evolution of economic activities does not occur between different types of variously specialised Sahelian families because they are not adequately specialised (Coquery-Vidrovitch and Moniot 1974). We hypothesize that such an evolution may occur within families, according to the balance of power and orientations between the different members of each family. Following Marks and Rathbone (1983) and Hansen and Strobel (1985), we consider that the external factors that have affected and continue to affect rural populations in this area may have several and important effects. To analyse family-related socio-economic changes, a first deductive methodology is analysing external factors and their impacts on family structures (Reinwald 1997) by comparing data on these external factors and family structures. However, in a low-data context, one may encounter difficulties accessing sufficient data on external factors for this a purpose. Moreover, one can only gain access to present-time family structures, leading to difficulties comparing family structures and external factors from a diachronic perspective. There is thereby a need for a tool that can consider the impact of family structures on external factors, such as economic, spatial and demographic elements, for which historical data are more available in order to test the existence of various family structures along history.

3 These evolutions were perceived with a large delay (and typically through various ideological prisms) by rural development operators, whose backgrounds are mainly in the biophysical sciences. These operators have little genuine connection with social science literature and are not encouraged to because of their background, as they build "interpretative models oriented by their discipline without acknowledging the subjective aspect of this interpretation" (Olivier de Sardan *et al.* 1995; Bonnal *et al.* 1997; Lavigne-Delville 1999). Therefore, the majority of development projects present families as a stable structure, based on the enlarged family archetype. Multi-activity, multi-finality and multi-decision are considered by these operators; however, in terms of practical usage, development programs rarely include such points[3]. The fact is that "the main weakness of anthropology [and other social sciences such as history] is

that it produces knowledge and not decision for action. How can one organise action based on the often very subtle and multiform framework of the [social scientist]?" (Bonnal *et al.* 1997). Many present-time biophysical scientists working in West African rural areas continue to justify research proposals on assumptions that deny the three points of multi-activity, multi-finality and multi-decision[4]. However, these factors are a structural characteristic of these societies (Milleville 1989; Paul *et al.* 1994). How can one demonstrate the effects of social factors beyond a qualitative description in low-data contexts? To do this, a tool that can gather environmental, social and economic aspects together and balance their impacts at the relevant decision unit (i.e., the individual within his/her household) is necessary (Saqalli *et al.,* 2010)[5].

4 Therefore, the current research has two objectives: (i) By combining all economic activities at the relevant level, we propose to show that family types, *ceteris paribus*, have a strong impact on Sahelian village populations and territories. More precisely, we investigate the impacts of family organisation on family economic activities and sustainability, explicitly considering multiple sources of income. This is accomplished through a modelling approach that can assess the consequences of the interactions between individual strategies within a family, as affected by family structure. These interactions are neither necessarily coherent nor necessarily antagonistic. (ii) In our study context, family changes may have occurred but no data are available. Therefore, we propose to analyse the family types' evolution along the post-decolonisation era through a diachronic comparison between simulation outputs and the rare data available as well as through an analysis of the family types' effect on population resilience.

5 As previously mentioned, the enlarged family was dominant and development operators continue to consider it the archetype. Meanwhile, field investigations, as assessed by Saqalli *et al.* (2010), demonstrate the present-time dominance in Sahelian Western Niger of a different family type, i.e., mononuclear families. We position our work in the economics debate between unitary structures[6] and collective non-cooperative structures (Donni 2004; Radja 2004). The latter correspond to a multi-decision family organisation in which there is a collective organisation but that is not based on cooperation efficiency, as defined by Pareto (Meignel 1993).

6 Family type proportions are known only for the present-time. Therefore, the only relevant methodology is to compare two simulated villages, each populated with one family type, with (i) the external data available and (ii) each other. We compare one-family-type villages rather than villages with a mixture of both family types (as is observed in reality) because this is the best first step in explicitly demonstrating the impact of family types, all other things fixed and defined. A family type mixture analysis is a further step after the demonstration of the impact of family types. Two family structures are then compared, these include:

1. The collective non-cooperative family. This is currently the most common family type in the study region (Tahirou 2002 p.23), with a Non Cooperative Family Structure (NCFS). This structure constitutes 76% of the families of the sample collected by Saqalli *et al.* (2010).
2. The unitary concept of the enlarged family. This is development agencies' main concept of African families, hereafter referred to as the Unitary Family Structure (UFS).

7 We used the SimSahel model of Saqalli *et al.* (2010). These authors built an empirical individually-based multi-agent model of a Sahelian village on the commune of Dantiandou, also called the Fakara (region of Tillabery, Western Niger). We chose Agent Based Models (ABMs) because they are particularly useful for simulating the multi-disciplinary approach of a multi-sectorial reality (Berger 2001). This is due to their capacity to integrate and formalise information and data of various forms, origins and disciplines (Rouchier and Requier-Desjardins 1998) and thereby, their power for allowing the emergence of global phenomena due to apparently minor and micro-level dynamics (Bousquet and Le Page 2004). From a historical point of view, because ABMs combine biophysical and social elements at the relevant level and can integrate temporal evolutions of social phenomena, it is useful to integrate them into a methodology in which hypotheses concerning micro human individual

behaviour are tested and compared with external macro diachronic data. The model results provide sufficient confidence for this type of comparison. The model can be considered as adequately reliable and as providing enough confidence in terms of consistency between global population-level results and field observations on the same Fakara site from other sources (Loireau-Delabre 1998; La Rovere 2001; Tahirou 2002), adequacy regarding micro-behaviours as observed during field anthropological research assessed in this field site and meaningful reactions to a sensitivity analysis (Saqalli *et al.* 2010).

Methodology

The overall field and modelling methodological approach

8 The entire work of model construction can be seen as an iteration of 'there and back's' between field working and modelling, as discussed by Rouchier and Requier-Desjardins (1998). We based our analysis on a previously built empirical and KIDS agent-based model that describes a village archetype (Moss and Edmonds 2005; Janssen and Ostrom 2006). The selected ABM platform is CORMAS (Common Resources Management Agent-based System), developed by CIRAD (Bousquet *et al.* 2001).

9 To understand the complexity of a farming system, our first assumption is that taking into account all its components and simplifying them is more relevant than neglecting some activities by focusing on the one which seems to be the most important. Our second assumption is that taking into account the strategies of all the members of a family and simplifying them induces a lower gap than simplifying it to a unique "household" strategy. Finally, our third assumption is that, as villages should be considered as open systems, it means that one may found more consistency in local but imprecise values, figures and relations than ones coming from literature describing equivalent but not local situations. Thereby, our modeling approach was supported by a long-term field investigation period (1.5 years) required to define the local context, the main differentiation factors between villagers and a villager-based typology of access to economic activities.

10 The field and modelling methodology, including the parameter functions and related sources for the agro-ecological and village socio-economic modules, is fully described in Saqalli *et al.* (2010). This paper also contains the individual-centred model, with relationships and dependencies between villagers (gender & rank as main factors of hierarchy in the family; lineage & individual and family wealth as the main factors at the village level) as well as their differentiated access to economic activities (agriculture, livestock keeping, seasonal migration, dry season gardening). All of the field (assumptions & steps) and modelling methodology (assumptions, parameters & rules) as well as the validation process (comparison with external data, sensitivity analysis) are thereby described in the Saqalli *et al.* (2010) article.

11 The temporal scale is defined as one week for each time step. The model is spatialized through a dynamic 100*100 pixels map as the main interface for the visualization of interactions, each pixel corresponding to one hectare.

Field researches

12 The behaviour rules are based upon the translation of the investigations that were conducted on the Fakara, according to an interpretation process similar to that of Gladwin (1989). The area (approximately 2000 km² and 40 villages and hamlets) is located 70 km northeast of the populated valley of the Niger River and Niamey, the capital city of Niger (800,000 inhab.). The eastern border is the populated fossil valley (56.36 inhab.km^{-2}), called "dallol Bosso". The Fakara is crossed by a network of dry and thin talwegs (less than 5% of the total surface) where dry season gardening can be practiced. Wide sandy plains extend from these talwegs, representing 75% of the area and the major part of the arable land. The remaining 20% is covered by hardened lateritic plateaus, which can be used only for pasture and wood gathering (Loireau-Delabre 1998). The dominant ethnic group is the Zarma, who are mainly farmers who increasingly keep livestock (Olivier de Sardan 2003; Saqalli *et al.* 2009).

13 Village and regional interviewing tools (Saqalli *et al.* 2009) helped to select the relevant villages in which individual interviews have to be done. Four villages were then chosen

based on size, access to dry season cropping and roads. The villagers' sample was defined upon a two-criteria stratification. Gender is the fundamental criterion of discrimination with respect to the access to activities. The second criterion is the level of responsibility, i.e. the number of dependents. We used semi-direct interviews focused on the main activity carried out by the interviewed person at the time of the interview: we have looked after the adequacy between the timing of the interviews and critical dates for each activity. Each person was interviewed once or twice depending on the number of activities he/she manages. 126 persons were interviewed, not including investigations on village history with elders and village chiefs. Individual interviews provided social rules that condition the differential access and power of each individual, which should be parameterized by field location- relevant figures, coming from our own interviews and other "grey" sources", i.e. reports from NGOs and other institutions working on site. Because of data uncertainty, these parameters are defined as relative to compare and hierarchize elements and factors for each village individual, thereby avoiding artificial threshold effects due to gaps between values coming from different data sources. Finally, we used theoretical hypotheses found in the socio-anthropological literature that describe social and environmental dynamics as supports for developing hypotheses and testing evolution scenarios.

A field & modelling process

14 The focus of the current work is the impact of family organisations on population developments. Therefore, the main principle we followed was to implement field observations as sequences of behaviour without introducing external postulated rationality.

15 For the entire biophysical module (climatology, pedology and phyto-ecology) as well as for all functions that are not related to socio-anthropological logics of production means management (demography, price evolutions of non-local products), rules and parameters are based upon the available published or unpublished literature (Reports & documents from development or research agencies, M. Sc & Ph. D. dissertations). The Fakara research site was selected because of the existence of extensive literature and data sets resulting from 20 years of agricultural research that was completed by several institutions (mainly ICRISAT, ILRI, INRAN, and IRD). The site can be considered as representative of the average situation of the rainfed Sahelian Niger. For the agro-ecological portion of the model, the villager-based criteria were defined through the available literature data (Gérard *et al.* 2001; Turner and Williams 2002; La Rovere and Hiernaux 2005).

16 The model is split into an agro-ecological part and a socio-economic part.

17 Climate and land dimensions were simulated through the cellular automata matrix of the model, where each pixel is a parcel of the village territory. Livestock agent behaviour rules and biophysical constraint hierarchy are defined from criteria identified by the villagers and from literature: for instance, the list of the main factors to describe a piece of land (fertility, gardening capacity, reaction to rainfall, weeding, grazing and weed growth) were defined through interviews, but the description of these factors are defined through literature and unpublished research data.

18 For the socio-economic part, we developed the entity-centered ABM concept by choosing individuals as the main model agent entity and not households or families, without introducing external postulated rationality, following Janssen and Ostrom (2006). No ultimate goal is defined, as all agents are reactive. Agents are defined as equivalent, which means that they have the same attributes: only the values of these attributes vary, defining each agent and its characteristics.

Building an agro ecological module

19 Rainfall can be considered as the unique climate factor to impact on local systems. The challenge was to simulate its high spatial and temporal variability. Seasonal rain variability comes from ICRISAT rainfall data (La Rovere and Hiernaux 2005, Gérard *et al.* 2007), as well as the spatial correlation of rain events at the village level. Climate simulation is done through a 5*5 pixel "Climate Blocks" matrix. For each time step, each block receives a rainfall probability, and if it rains, a probability for the rainfall quantity. Both probabilities are then

affected by a drought factor, randomly defined at the beginning of each year, varying from 80% to 130% of the average rainfall.

20 The village territory is spatially described through a layer of pixels (i.e. "parcels"), where each cell has an initial agro-pedological fertility potential P: the plain (P = 1), the valley (P = 2), the village and the plateau (P = 0) are simplifications of the soils' qualitative description of Glättli (2005). Each pixel fertility value is initially equal to the parcel's potential and then varies according to the vegetative growth of grass and shrubs in the pixel, defined by local pixel rainfalls, fertility, cropping impact for owned and cultivated parcels and manure.

21 The fields' manuring and grazing impact is defined along a ratio between surface and the number of animals of each species. At each step, a parcel may be grazed / browsed depending on the species (i.e. preferentially shrubs for goats, preferentially grass for the others). Cattle are differentiated between a calf and milking cow group, staying on the village territory while weaning and milking, and a "dry" group, leaving for transhumance during dry seasons. The manure from the remnant herd is then defined for each animal specie for each pixel: half of one animal manure is spread in grazed areas (at day time) and the other half in corrals at night (Ayantunde *et al.* 2000; Ayantunde *et al.* 2002): this last part of the manure is then spread solely on the fields of the animal owner, which means that this action leads to a potential differentiation between fields according to the field owner's herd.

Simulating the villagers production activities

22 *Agriculture*. Rainfed agriculture is the main activity in terms of land use and manpower requirement during the rainy season, from June to October (Tahirou, 2002). Sowing (sometimes several times if it remains possible for seeds to grow), weeding (at least twice according to weed levels) and harvesting are the most labour-requiring production steps. Only male adult agents can crop millet fields. Only household heads can extend the family property according to family needs and manpower.

23 Therefore, one parcel produces only if it has either been appropriated or borrowed by a villager agent. Each week, the villager agent observes his parcels' status and calculates the available manpower he can use (his own and his dependent relatives who are available, according to the family structure). He then classifies priorities and chooses the field so as to minimize the loss of production over all his fields. Crop growth is then governed by the available manpower at the right time, rainfall and the fertility rate. Weeds evolve according to parcel fertility, rainfall and weeding actions (Lassina, 1992; Montagne and Housseini, 1998; Sangaré *et al.,* 2001; Schlect *et al.,* 2006) and affect millet production until millet is higher than weed. Crops yields result thereby from a combination of the crop growth rate, weeds and fertility effect rates.

24 Dry season vegetable gardening follows an equivalent sequence of actions. Dry season vegetable gardening can be practiced only in the villages that have access through wells to shallow groundwater in "valley" fields. Only married women/widows with daughter-in-laws or unmarried daughters can garden, by mobilizing the available female manpower from then on in a similar fashion than the family head millet farming. This activity can generate around 52.50 € per woman per year, at the end of the hot dry season, roughly April.

25 *Migration.* Seasonal migration occurs during the dry season, from October to May. Most of the male adults move to the Gulf of Guinea basin to find jobs (Timera, 2001). The money they earn is a major source of income for the entire Sahelian zone (Reardon, 1994). Furthermore, the money they bring home, approximately 290 € per family per year or 30 € per inhabitant per year, is an important contribution to the remaining family members (Mounkaïla, 2003; Saqalli *et al.*, 2011). Racket of custom services often occur on migrants while they cross the border coming back. Migrants use the money for food, religious and/or social ceremony spending purposes, small ruminants, savings and/or the next migration travel expenses. Departure time is typically after crop harvest but many young bachelors leave earlier. Only male adult agents more than 16 years old have access to the migration activity. The price for the roundtrip travel is the major constraint for leaving. The date of departure depends on the family rank, i.e. the number of dependent relatives. To come back, the migrant should overcome two constraints: (i) for prestige reasons, a male adult agent cannot come back in the village without at least

the roundtrip ticket for the next migration, i.e. 2* 45 €. (ii) Each male adult agent has a 1% probability to be racketed by the different customs services he meets. We defined a weekly gain accumulation function as follows:

$G_i\ (t+1) = G_i\ (t) + g_i\ (t) * [1+(N_i / 10)]$

26 With: G_i (t+1) and G_i (t) gains of the individual i, respectively at time t+1 and t, N_i the number of years of experience of the individual i, g_i (t), the weekly gain: g_i (t) = 6 from the beginning of July to mid-December, g_i (t) = 15 from mid-December to mid-February, g_i (t) = 2 from mid-February to the end of June.

27 *Livestock keeping*. It is here limited to a saving scheme, except its impact on the fertility process. Each year, individual gains (crop yields for family heads, migration for men, gardening for women) are "thesaurized" into livestock, with a depreciation factor: Villager agents buy animals after crop harvest or coming back from migration, when they have grain to sell; however, it is the time when millet price is the lowest (13.75 € in average per 80 kg bag). When the granary is quite empty, villagers sell livestock, usually at higher millet prices (27.50 € per bag: 50% loss).

Implementing social relationships within families in a Fakara village

28 At the model initialization, fifty age and gender defined villager agents are created in the virtual environment. A mortality probability is also defined, growing along age, eventually producing a life expectancy of 48,5 years-old for both genders as described for the arrondissement in the UNDP report (UNDP, 2005). Each male agent has a randomly defined lineage, from 1 (the best) to 4 (the lowest), as a measure of the power of each big kinship group. This value is transmitted to all progeny and wives. Each male adult agent takes one piece of land as a new property, containing several parcels, according to lineage, between 3 and 7 parcels. The size of the land property can extend thereafter according to available family manpower and lineage. Choosing new parcels within free parcels is based on distance to village and parcel fertility (Loireau-Delabre, 1998 p.170-186). Male adult agents can then get married and create a family with themselves as the head.

29 After the model initialization, gender and family rank for a villager agent are the most important social factors (Olivier de Sardan, 2003), determining access to all social and/or economic activities, i.e. marriage, property, food and money redistribution, millet farming and migration for men, gardening for women.

30 Ranks are defined for all child agents but vary for all adult agents in each family. They are updated at the beginning of each time step, according to newborns, new marriages, reaching adulthood and deaths. The highest ranking index, i.e. the family head, is equal to 1. From then on, the following rules are applied:

1. For each male adult agent, the ranking index increases by one point if the father is alive and for as many points as the number of elder brothers he has got.
2. At wedding time, female adult agents move to their new husband's family. Ranks of married female adult agents are equal to their husbands' rank, plus one point.
3. Ranks of unmarried female adult agents, i.e. unmarried sisters in a family, are equal to the youngest adult male of the brotherhood plus one point.
4. From then on, dependent relatives are defined for each adult agent: they are members of the same family, with a lower rank, and related to him/her by marriage or as progeny.

31 As we do not focus on marriage rationality, we did not implement a negotiation between candidates as theorized by Simon (1955) and implemented for agent-based simulation by Small (1999) or White (1999), and we rather used an assortative mating principle following Becker (1974): marriages are matched by comparing mating members. Muslim men marry up to four times if they can afford the costs. After majority (16 years old), marriage is conditioned by the payment of the dowry, usually thanks to the money from migration. Males sort female bachelors according to family characteristics (lineage, size, wealth, livestock and land) and personal ones (rank, livestock). As a strict condition to own land and thereby to become a "citizen" in the village, each male adult agent has to marry at least once. Earning enough

money to afford the dowry is therefore vital for each bachelor in his village. Dowry reaches 300 € but varies according to the lineages of the two families. In the simulation, only married women can have children. Newborn agents are created with a random gender, as a member of a family, a lineage and a village. Simulated ceremony costs are taken from the family balance as a sheep-equivalent cost.

32 Inheritance does have sense only for a landowner's death. We have followed a "brutal" version of the common law: the elder son receives the whole heritage, leaving the others to exploit new lands somewhere else (Luxereau and Roussel 1997). As long as there remain adult family members, the one whose rank is the best becomes the new family head and heir. If there are no adults anymore, the land is given to the family head from the same lineage. The heir adopts the remaining children.

33 Each agent has an individual food balance. Food redistribution is the most important hierarchy procedure within a family. At each time step, each adult agent classifies its dependent relatives with a negative balance according to "social distance" between ranks and according to social groups (gender, marital status then age). Women with the highest rank may be family food distribution managers while men are out in migration, usually the wife of the family head. This corresponds with the observed commensality, particularly in big families, where strongest productive elements seem to be favored in a family. If a family member balance is not fulfilled by redistribution and its value is negative at the end of the step, the villager entity is suppressed and considered as dead.

34 The two types of family organisations, namely the patriarchal and unitary type and the non-cooperative type, are compared in Table . This comparison allows us to propose a deterministic hypothesis of the evolution of the unitary family towards the mono-nuclear and non-cooperative family.

35 All behaviours we described are then affected by these organisations as they condition the required assets to realise economic activities. For instance, seasonal migration departure is conditioned by the cash capacity and both agriculture and gardening family manpower needed, which depends on the family organisation. To compare these two types of family, we simulated villages with only NCFS families in the NCFS scenario and only UFS families in the UFS scenario. For each scenario, 15 simulations were run along 3120 time steps, meaning a period of 60 years (i.e., two generations) each of. Simulation outputs were obtained for the entire village at the following levels: family, gender and age group.

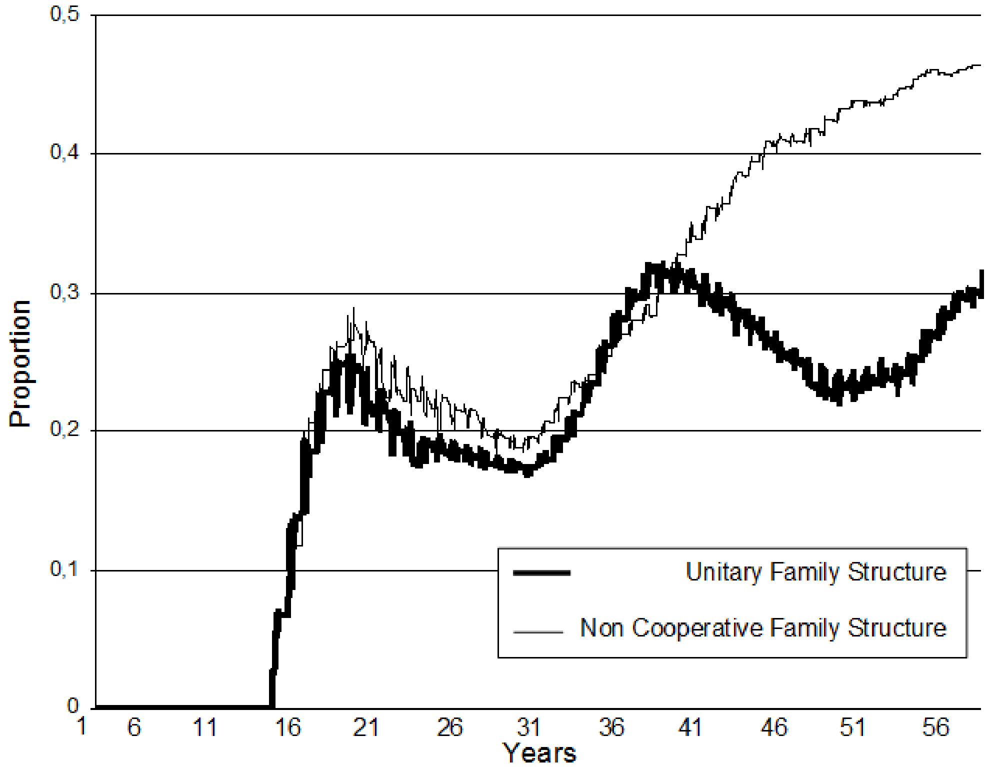
Results and discussion

Millet farming as a basis, others as necessary activities

36 Simulation output shows that gardening practice is strongly affected by the generation effect in both scenarios (Figure 1). This is because female gardening is an activity that requires female manpower under obedience, which is possible only after the establishment of the required family network. Therefore, this generation effect is artificial. As we have no information on the social network before the village foundation, networks must be built to induce such generation waves. Available female manpower is a constraint that can be fulfilled only after a dozen years.

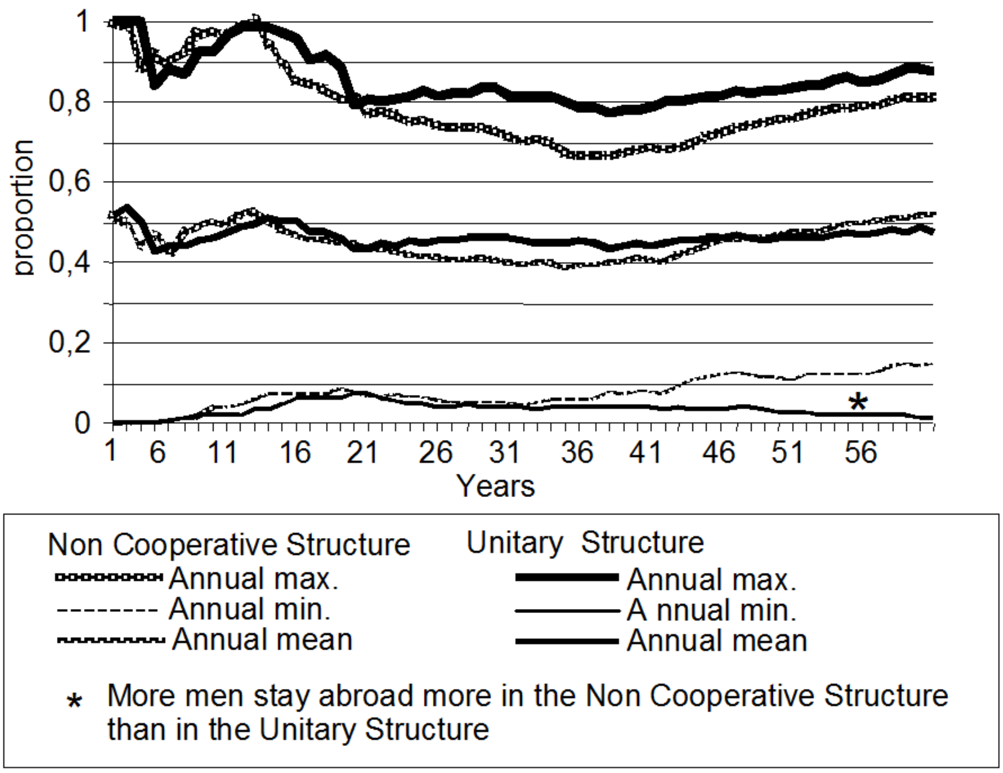
37 Beyond this generation aspect, it is noted that this activity spreads less rapidly or even decreases in the UFS. Stepdaughters always stay in the family of their mother-in-laws in this scenario and because they must work for the mother-in-laws, these stepdaughters cannot start their own garden even if their manpower conditions are fulfilled. In the NCFS, the splitting of the population into numerous small families makes it possible for many female adult agents to garden, but only when they have reached the appropriate age. As a result, the generation factor is a strong constraint for female adult agents in the UFS whereas the number of female gardeners increases rapidly in the NCFS.

Figure 1: Simulation outputs for the proportion of female gardeners



38 For both family structures, simulations show that the proportion of male adult agents who migrate remains quite constant, approximately 50% (Figure 2).

Figure 2: Simulation outputs for the proportion of men who migrate



39 Between the 20th and the 45th year of simulation, many young second generation families are created, but their children are not yet adults. In the NCFS, male adult agents must stay longer in the village, at least until the millet harvest, as they are alone and cannot obtain help with the work in their fields. This explains the dip observed in the proportion of migrants during that period, represented by the two annual maximum value curves corresponding to the two

scenarios. On the other hand, in both scenarios, the annual minimum value curves show that a certain proportion of male adult agents remained abroad for an entire year at least once (see the * on Fig. 2). These men are unlucky (we introduced the risk of custom services' racket of one “chance” in 100 in the model based on interviews) and/or too inexperienced to bring back a sufficient amount of money at the end of the dry season. This is particularly an issue in the NCFS as family assistance cannot compensate the loss.

40 The need to remain abroad for more than one dry season is reinforced by the fact that the essential condition of access to land is marriage. The number of migrants who remain abroad for more than one dry season increases with the number of young adults. The male average age for marriage is 17.4 years (± 0.3) for the UFS and 20.6 years (± 1.1) for the NCFS. Thus, the rule we proposed of the anticipated departure of youngsters during the cropping season has little effect in the NCFS. Because male adult agents quickly claim their independence in the NCFS, this rule applies only during the short time the young male adult agent is unmarried because he has not yet accumulated a sufficient amount of money. Forcing a son to work in the fields can be considered a father’s last resort when he cannot afford or does not want to pay his son’s marriage costs. Married male adult agents migrate, but they remain abroad for a shorter time (25.4 weeks versus 38.7 weeks for the bachelors in the UFS; 31.7 weeks versus 40.2 weeks in the NCFS). Finally, because migration delays marriage in the NCFS, the total population increases more rapidly in the UFS. The average value is 497± 275 in the UFS while the NCFS has an average value of 178± 47.

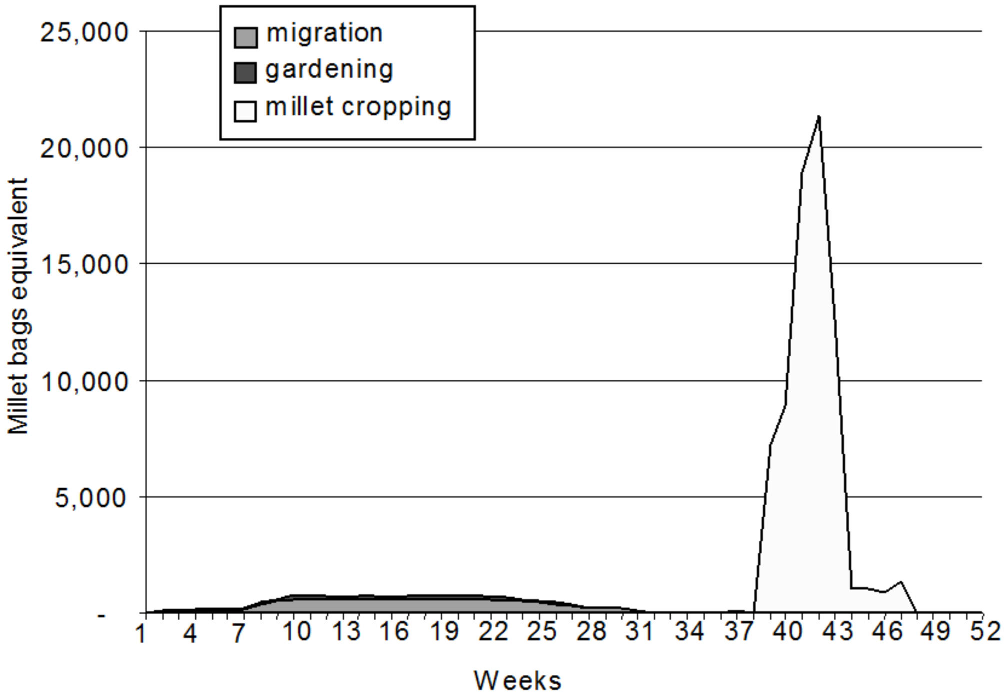
Table 1: The simulated characteristics of the two simulated family structures

	Unitary Family Structure (UFS)	Non Cooperative Family Structure (NCFS)
Family structure	Married sons remain at home;	Married sons leave home and build new families
Condition for marriage	The family head, most often the father, pay the dowry.	The « fiancé » pay the dowry.
Sharing food	All income is given to the head of the family, who shares them among members[7]. Therefore, the family balance is equal to zero when he dies.	A « family granary » as an account to share to fulfill the demands of family members. Family members’ balances are maintained whatever happens to the head of the family.
Availability for seasonal migration	The head of the family defines his manpower needs for each millet cycle stage. Only him can allow a young male family member to leave earlier for migration	A young male family member can leave for migration during the millet-cropping season if there is still an elder with a higher rank staying at home.
Fields extension	Families do not explode and cropland expands based on family needs	The direct heir has all the inheritance; others have to settle somewhere else.

41 As indicated in Table 1, simulated activities represent quite different proportions in the villager agents’ income. In the UFS, the proportion of total income derived from millet agriculture is particularly important due to migration and marriage rules. On an annual basis, the sequential organisation of activities (gardening then agriculture, followed by migration with some overlap) is an incontestable advantage for the populations’ survival in both scenarios.

42 Figure 3 presents an example of a yearly distribution (year of simulation = 50) of these sources of income in the UFS. In terms of economic activity set up, leaving the management of all assets in the hands of the head of the family provides to this one a slightly stronger power.

Figure 3: UFS simulation outputs of the annual village production for the three simulated activities



More food for all, same quantity for each

Income & inequalities

43 The two scenarios present a level of income that evolves differently, with an average advantage of 48% at the end of the simulation for the NCFS. This is because the cropped surface is more adequate for the population and the migration time lengthens after the 18th year of simulation. However, simulated income distributions differed between the two family structure hypotheses for the four strategic groups, defined on the basis of gender and level of responsibility criteria. Married male adult agents provide the main source of income through millet cropping and migration activities. For this group, millet cropping is the largest source of income but this production cannot be considered as usable cash. This is due to the fact there are few opportunities to use millet cropping as a source of investment because it is meant almost entirely for consumption. The contribution of married female adult agents in the overall income is notable, contributing approximately 10% in both scenarios through the gardening activity only. Without this activity, they would be in the same unsteady situation as unmarried female adult agents. Moreover, garden products are “providentially” available at the beginning of the harsh season, between April and June, directly before the males return from migration. The contribution of unmarried male adult agents is artificially inflated: the income they accumulate during migration is important. They place a large part (80% in our model) in the common balance, i.e., the domestic granary for the NCFS and the family head balance for the UFS (in the latter case, the head of the family can transform these gains into livestock). It should also be noted that migrants are fed during migration times; therefore, their balances are not affected by consumption. Finally, unmarried women and child agents do not earn incomes because they are not formally “producers” (one should add strong quotation marks to this word as the work that women must do is vast but we mean here that they have no personal gain from it) in the model.

44 Regarding economic activities, the unitary family structure seems more "productive" due to earlier marriages. This social organisation, by lifting some social obstacles, allows a faster growth of the population and a larger extension of cropland. However, it does not raise the average standard of living compared to the NCFS.

Fertility, livestock & sustainability

45 The livestock populations are not equivalent in terms of both size and species distribution. The NCFS scenario produces 162.43 livestock units on average (105.60 Large Stock Tropical Units (LSTU)), while the UFS allows 463.12 units on average (341.75 LSTU). The transhumance, by sending away all of the "dry" bovines (i.e., all bovines but calves and feeding mothers) during the dry season, has the same effect on the local environment as does human migration. Simulations tested without transhumance produce a collapse of the grazing capacity, soil fertility and hence the entire farming system. Largely due to the family heads' higher capacity of investment, proportion of cattle is higher in the UFS than in the NCFS (67.24% versus 56.27%) while the proportion of sheep is paradoxically lower (3.45% versus 3.90%) (Figure not provided). This difference is nearly significant and may be due to a higher concentration of the money in the hands of the migrating head of the household, while women are left without investment capacity during the dry season. Meanwhile, the livestock per capita ratio is higher for the NCFS than the UFS (0.54 versus 0.43), which should be related to the better income per capita standards of the NCFS scenario.

46 Result outputs suggest that the UFS scenario induces more stress on the biophysical factors supporting the farming system. Land occupation is twice the figure for NCFS (50.35% versus 26.89%), due to the higher population growth (no significant differences appear in the land per capita ratio), while yields per ha remains equivalent as long as there is sufficient land to compensate for the permanent loss of fertility of the cultivated fields. This indicates that a fully saturated situation will appear far more rapidly in the UFS than the NCFS situation (between 20 and 30 years after the end of the 60 years simulation for the UFS versus 50 to 60 years for the NCFS). One should then question the sustainability of such a family structure in this environment.

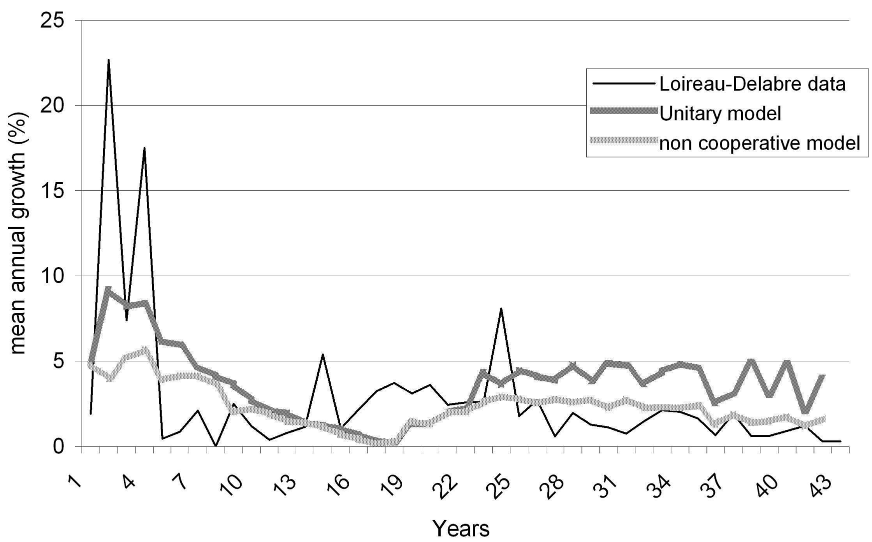
A hypothesis about a change in local social organisation

Comparison with diachronic historical data

47 As Loireau-Delabre (1998) is currently one of the best references on the Fakara recent history, we compare the evolution of the acreage of cultivated fields that she simulated and the model simulation results. Loireau-Delabre's acreage is derived from five aerial photo interpolations (1950, 1965, 1975, 1985, 1992). The Loireau-Delabre results (Figure 4) for the first 20-year period show a similar cultivated surface growth rate as that of the UFS simulation results, with a value higher than 3% per year. For the next 20-year period, the Loireau-Delabre results show a decrease of this rate that corresponds with the simulation results of the NCFS, with values of roughly 2% per year, whereas the UFS scenario results in an acceleration of this cropland expansion.

48 The social constraints that we implemented can be considered as anticipators of the land tension: the more social constraints (no inheritance, no support from relatives, low manpower) a family has, the more difficult it is to obtain land. The NCFS scenario better illustrates the impacts of such social constraints on the decrease in population growth, mainly due to the lack of support for the creation of new families. Analysing these results, we propose the hypothesis of a shift in family organisations during the 70's, from the patriarchal type to the mononuclear type. It means that famines that would have occurred in this decade had only catalytic effects on a shift that would have been realised regardless.

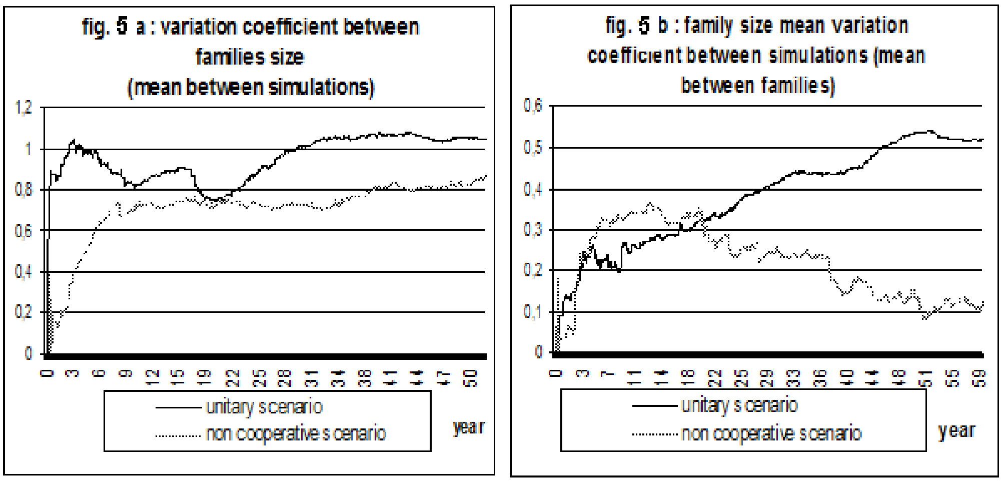
Figure 4: Comparison of the annual growth rate of cultivated land for the two scenarios simulation outputs and interpolated data from Loireau-Delabre (1998)



Mean annual cropland growth rate	Loireau-Delabre data	Non cooperative Family	Unitary Family
All years	2,22% per year	2,32% per year	3,68 % per year
First period (1950-1972)	3,91% per year	2,45 % per year	3,35 % per year
Second period (1973-1993)	1,65% per year	2,18% per year	4,03 % per year

Analysing family type resilience facing environmental fluctuations

49 The two scenarios show that the family types do not have the same resilience (Figure 5).



50 Fig. 5a Simulation outputs for the variation coefficients between Families size (mean between simulations) shows the difference within each simulation between families. More the coefficient variation value is high, more size differences between families are high: actually, in the UFS, only having daughters in a family ineluctably leads to the disappearance of this family. Family concentration in big clans is then an inescapable phenomenon in the UFS scenario (7.7 families with 103.7 persons per family on average in the UFS versus 17.2 families with 11.3 persons per family in the NCFS at the end of the simulation), even reaching 420 people for one clan in some simulations! The social organisation that we observed during field investigations and as described in the NCFS suggests that this system prevents crystallisation into big clans and disappearance of small clans as observed in the UFS

51 Moreover, the risk of disappearance for a family, represented by the coefficient of variation between the simulations (Fig. 5b Simulation outputs for the family size mean variation

coefficient between simulations (mean between families)), is far more important in the UFS. This scenario is more risky, leading to a decrease in population in 25% of the simulations.

52 The higher demographic rate is not adequately compensated by agriculture, migration and gardening incomes, all three having too strong social and economic constraints to answer the needs. Therefore, the low-cropped land/family size ratio weakens the clans in the UFS scenario. Multi-activity, by diversifying income sources, is a protection against agriculture risks. The head of the household, by concentrating the manpower on agriculture, reduces the gains from gardening and migration. Multi-decision increases the access to other activities and is, hence, also a protection. In the UFS, the concentration of the "redistribution power" in one hand creates a notion of distance between each member of the family and the head, who manages the redistribution. This distance is defined by the rank of each member. In the NCFS, this distance is quite low because any food distributors can co-exist in one household including the head of the household. Therefore, a bad year, for various reasons, can easily lead to the collapse of the domestic architecture in the UFS, while NCFS families are less sensitive to poor yields and poor migration gains. Moreover, the collapse of a small family has a lower impact on the village's global demographic growth in the NCFS situation. Furthermore, multi-decision constitutes a protection as well.

53 We have used the fecundity coefficients of the 2001 national census; therefore, the simulated demographic growth rate is determined by the social organisation. A comparison of the two simulated scenarios suggests that the organisation of each is a caricature. The real food redistribution system is not always concentrated to such a high degree. Fathers often pay for their son's dowry, even when the latter has left the family. Furthermore, young adults can own parcels without getting married, etc.

54 The unitary approach can be considered a “productive and intensive” version of the local organisation. This type of organisation (i.e., a village centralised in big clans) is more frequent in the southern savannas of West Africa (Raynaut *et al.* 1997; Reardon 1994; Gastellu and Dubois 1997). A decentralised organisation, as is the NCFS, can be considered as a less productive but more resistant social organisation, which is far more important in Sahelian areas.

55 Our field data suggests that the concept of a decision-decentralised organisation within families (NCFS) has been dominant only for recent years, but as previously noted, this organisation was evident a century ago. Our investigations showed higher migration rates for 2005 than in the past. We suggest that family organisation evolves from a village in which unitary families are dominant to the currently observed non-cooperative families, as has been assumed by Loireau-Delabre (1998). Luxereau and Roussel (1997) and Mortimore *et al.* (2001) described this shift in the 70's for the region of Maradi, the south central part of Niger near the Nigerian border. They explained this shift with factors that we have considered (income bursting) and others that we have not (islamisation and capitalisation, population density growth). Furthermore, the shock of the severe droughts of 1973 and 1984 played a catalyst role. The fact that the average income level per head is lower in the UFS and that the income distribution is better balanced in the NCFS could have been strong incentives for the youth to escape from the enlarged family. We do not yet have other data to confirm this hypothesis.

Conclusions

56 A complete methodology of integration between sociology, history and biophysical sciences within a field and modelling pattern remains to be built as simulating a society and building an agro-ecological model have different scientifically relevant criteria. However, ABMs are currently the best tool for combining qualitative information and quantitative data. ABMs are a useful interface to introduce social stakes in development projects. However, agent-based model simulation outputs cannot be used to prove assertions, but this is the case for any model.

57 Regardless of the family organisation, men and women must participate in migration and gardening activities, respectively, in order to not completely depend on millet yields, particularly when incomes are not managed by the head of the family. Many development

programs in Niger, with the rise of the gender approach, are supporting women's gardens. Therefore, the same consideration should be applied to migration as this activity is not in competition with other activities in the dry season and procures valuable incomes for the area. Migration should not be considered as an indicator of local poverty, but as a means of action for development in Niger. As field results have shown, the average annual migration net return is 150€ for a 45€ annual investment. Therefore, allowing loans for this purpose may constitute a good support program, particularly through rainy season sheep fattening, which will be a quite profitable activity for the next few years as the Tabaski feast is celebrated at migration departure times.

58 While the economic activities distribution within families is predefined by gender, access to these activities as well as income levels and distributions are strongly affected by the family organisation. NCFS lowers the extension of the three economic activities by limiting access to the necessary assets: cash limitations for married youngsters' migration and lack of available manpower for gardening and agriculture. Delays in marriage slow demographic growth if support from parents is missing, as observed in the NCFS. The UFS family organisation is not adapted to the new Sahelian context, where land availability and family protection are no longer the buffer they once were, as they still are in more southern Sudanian environments. Consequently, a household approach no longer appears to be appropriate for implementing development programs in the Sahelian zone.

59 Finally, from a historical point of view, using such modelling tools helps in producing hypotheses on social and/or family changes and testing such hypotheses by comparing simulation results with the available data. Therefore, ABM helps to define an inductive methodology that may constitute a relevant alternative to deductive methodologies that require long-term and complete series of data, which are quite rare in developing countries.

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Notes

1 Nine villages out of ten in Sahelian Niger are less than 150 years old. Most were settled between 1910 and 1950 (Vanderlinden 1998). It was only after this first period that the territory was slowly utilised for farming: in 1950, only 10% of the surfaces in the rainfed Sahelian portion of Niger were cropped.

2 Olivier de Sardan (2003) recalls testimonies for such an evolution as far back as 1914!

3 For instance, the social obligation to contact the male family head as the representative of one "household" typically restricts the family interview to the father. Therefore, the accessible information is that which he provides. He may provide information on agriculture, the economic activity he manages and understands, and neglect to discuss his wife's garden or the seasonal migration activity of his son. This, in turn, limits development proposals to the father's sole point of view (Lavigne-Delville 1999). A large majority of agriculture-supporting programs are based on intensification, which is inherently in contradiction with diversification and risk aversion strategies.

4 See Quin'ones et al. (1997), Buresh et al. (1997), Ahmed et al. (2000) or Breman *et al.* (2001) as instances of articles following these assumptions.

5 For instance, in order to observe inheritance procedure evolutions, generations are required. The impacts of such evolutions cannot be assessed with deductive methodology in a context in which long-term data are unavailable.

6 Unitary family models consider the household or the family as a homogenous decision-maker for all economic and production activities (Sen 1983 cited by Meignel 1993).

7 All gardening incomes remain in the women's hands in the non-cooperative scenario whereas in the unitary scenario, even this money goes to the balance of the head of the family.

Pour citer cet article

Référence électronique

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Résumés

This research analyses the impacts of the family organization on the diversity of income sources and the sustainability and the dynamics of rainfed farming systems of Sahelian Niger, through an individual-centred agent-based model which variables were defined through anthropological investigation. Results show that family organisation has strong effects on wealth levels and distribution and on demographic growth. They also suggest a historic shift from the patriarchal mode to a mono-nuclear mode in the 70's in this specific area, due to a higher resilience of the latter thanks to a broader diversification and a better adequacy between wealth and family demography.

Reconstituer les transitions familiales dans un contexte de rareté de l'information : le Sahel ouest-nigérien de 1950 à 2000, une approche par les modèles multi-agents

Cet article présente la méthode et les résultats d'une analyse des impacts des modes d'organisation de la famille sahélienne sur la diversité des sources de revenus ainsi que la durabilité et la dynamique des systèmes de cultures pluviales sahéliens au Niger, et ce, au travers d'un modèle multi-agents individu-centré dont les variables ont été définies par une enquête socio-anthropologique approfondie. Les résultats montrent que l'organisation familiale a des effets importants sur les niveaux et la distribution de richesse individuelle et familiale ainsi que sur la croissance démographique. Ces résultats suggèrent également un tournant historique de basculement de la société sahélienne nigérienne dans les années 70, d'un mode familial patriarcal à un mode familial mononucléaire, en raison d'une plus grande résilience de ce dernier mode, du fait d'une plus large diversification et une meilleure adéquation entre richesse et démographie familiale.

Entrées d'index

Mots-clés : Sahel, Niger, structures familiales, modélisation multi-agent, société rurale, dynamiques socio-environnementales
Keywords : Sahel, Niger, family organisations, Agent-based modelling, rural society, socio-environmental dynamics