1.6 «WHEN «TANETY» HILLSIDES MEET THE RICE FIELDS AT LAKE ALAOTRA»: DIVERSIFICATION AND INNOVATION IN UPLAND ZONES IN AN INCREASINGLY SATURATED LAND OCCUPATION CONTEXT

Raphael Domas[1], Eric Penot[2] and Herizo Andriamalala[3].
BVLac project, CIRAD/BRL, Malagasy

[1] BRL/Madagascar (rd42@caramail.com), [2] CIRAD-ES, [3] BRL/Madagascar, [4] CIRAD

Abstact

Despite a 100% increase in the rural population every 18 years, the Lake Alaotra region is still an important area of immigration. Land occupation is saturated in the irrigable lowlands (well irrigated rice growing areas, rice fields with poor water management, and rainfed lowlands with access to groundwater resources in the dry season, known as "baiboho"). As a consequence expansion, in terms of new cultivated lands, occurs on uplands («tanety») surrounding lake plain. The diversity of soils, their fragility - with signs of erosion such as «lavaka» (areas of hill collapse) - intense deforestation in the valley lowlands and at the bottom of hills, and extensive cattle rearing initially based on common land have generated a huge diversity of landscapes and land uses.

Given this broad range of situations, development projects need to propose varied and locally adapted technical systems, and especially cropping systems generating regular and sustainable yields (based on risk reduction), soil protection from erosion and from roaming cattle culminating in a renegotiation of agriculture-livestock relations.

To that end, Direct-Seeding Mulch-based Cropping Systems (DMC systems), introduced and disseminated by the BVLac project since 2003, seem promising. Monitoring of hundreds of plots, supervised by BRL led to the creation of a reliable database containing the results actually observed in BRL farmers' fields.

Combined with a 'farm approach', taking into account farmer strategies and the constraints associated with the whole range of agricultural activities, use of this database provides a clearer understanding of local innovation processes related to this important change in paradigm for producers. Indeed, the novel techniques of agro-ecology call for a halt to ploughing or tilling operations, and the combination of plants which are sometimes unproductive but which generate positive externalities within the system. Moreover, these techniques go hand in hand with a certain degree of intensification, enabling optimum use of introduced improved varieties, suited to the soils and, especially, to the financial capacities of the farmers. Risk management and yield regularity lie at the core of these current innovative processes, which show remarkable flexibility in adaptation and adoption, and which may even modify farmers' behaviour when dealing with complex systems that need access to many services which are still in their infancy in the area.

2 Lake Alaotra : a land of migration and strong population expansion

The Lake Alaotra basin is one of the largest rice growing areas in Madagascar, with almost 100,000 ha of rice fields, of which 30,000 ha are irrigated and 70,000 ha have more or less poor water control. It is one of the rare zones in the country with a rice surplus.

The population, which mostly comprises the Sianaka (ancient migration) and Merina (recent immigration) ethnic groups, doubles every 18 years and currently stands at 700,000 people. Agriculture, which is traditionally practised in the Lake plain and the upland grasslands, and is mainly geared towards rice growing and extensive cattle production, has evolved considerably since the 1960s, under numerous development projects. With strong population pressure and the saturation or even retreat of rice growing areas in the lowlands and bottomlands due to sanding up and flooding, farmers started colonizing the surrounding uplands in the 1980s, using cultural and pastoral practices that are particularly erosive on the fragile soils. This situation gives rise to a dual challenge: developing cropping systems suited to upland conditions on soils that are generally quite poor, and promoting a new type of agriculture-livestock integration. In addition, this region appears to be threatened by stagnating rice production in the irrigated zones, most of which have not been maintained since 1990 with the end of Somalac (Société de développement de la riziculture au lac) (Devèze, 2008). The drop in yields over the cropping cycles, and major signs of erosion (visible on a cultivated plot and a landscape scale) are the main indicators of the unsustainability of these systems.

The zone covered by the BVLac project (AFD) includes vast expanses of degraded uplands and limited plain areas, mostly composed of random irrigation rice fields with poor water control (RMME). The main development issue is therefore substantially to improve productivity in the lowlands and sustainably develop upland zones with worthwhile agricultural potential. Direct-Seeding Mulch-based Cropping Systems (DMC) seem to provide alternatives based on an environment friendly agriculture that provides attractive income to farmers. As most of the cover crops used are intended for food or fodder use, the integration of agriculture with livestock rearing also becomes possible (plot animal and animal plot transfers).

The NGO TAFA set up the first DMC trials at Lake Alaotra in 1998 (Annual Reports, 2001, 2005). Technical frames of reference for land development, which are more or less adapted to the very wide diversity of situations encountered, have thus been drawn up and made available to the different agricultural extension operators since 1999 (mostly manuals and information leaflets produced by the Madagascar Direct Seeding Group (GSDM), etc.). For its part, the BVLac project launched its operations in 2003. The cropping systems disseminated are intentionally highly diversified in order for them to be adapted to the numerous cropping situations and farm categories encountered. In the rainfed lowland areas, a double annual crop is possible, alternating a cycle of short-cycle rainfed rice in the wet season with an out-of-season legume cover crop or mulched market garden crops (also of great interest to farmers). Use of SEBOTA [1] type versatile rice varieties in alternation with cover crops makes it possible to develop rice fields with poor water control (RMME). Lastly, a diversified range of cropping systems[2] is proposed for developing uplands in the wet season with an alternation of various cereals, legumes and cover crops, sometimes for fodder use.

Within the BVLac project, these different techniques are disseminated by several operators: AVSF[3] and ANAE[4] to the west of the lake and BRL/Madagascar to the east. The cropping systems currently presented and extended incorporate various levels of organic or mineral fertilization adapted to farmers' financial possibilities and production objectives. A annually updated «plots» database can be used to monitor changes in the plots, in yields, in crop management sequences and in the main cultural practices, in order to measure the true impact of the project, the practices arising from its dissemination (knowledge and know-how) and the innovation processes (adaptation/transformation and partial or total adoption of the systems).

[1] *Mixed rice varieties selected in Brazil that are able to develop under irrigated and/or rainfed conditions. They are highly productive and possess organoleptic qualities appreciated locally by consumers.*
[2] Cropping systems notably combining maize or rainfed rice with vine legumes or cassava with fodder crops. Rainfed rice or underground food legumes on dead mulch also give good results.
[3] Agronomes et Vétérinaires Sans Frontières
[4] Association Nationale d'Actions Environnementales

Figure 1: BRL Madagascar operating zone under the BVLac Alaotra project

3 A recently implemented «farm» approach

The initially developed plot approach showed its limited efficiency, with a high rate of abandonment from one year to the next (over 35%). A new «farm» approach taking into account all production factors that guide farmers' choices with all the corresponding components has been adopted since 2007 (Penot E., 2007, 2008). This approach also integrates the concept of activity systems in which a farm and a household co-exist with agricultural and off-farm activities and incomes. A farm typology was constructed from an analysis of farm characterization surveys undertaken in the zone in 2006 (Colleta M. and Rojot C.) and primarily in 2007 (Durand C. and Nave S.), which was discussed then adopted in 2008 by all the operators.

Agricultural development action is combined with individual or collective environmental protection action, in order to guarantee the good condition of downstream hydro agricultural infrastructures, but also to guarantee the productive capital of the land: revegetation of degraded tanety slopes using hardy plants with high restructuring capacity, installation of hedgerows along contour lines and reforestation, etc.

These different actions turn to account natural regulation processes. Indeed, the areas devoted to hedges, reforestation, hillside and valley grasslands and grassed strips retain water, soil and pollutants. The approach developed by the Project recommends mixed farming systems combining annual and perennial crops, along with animal production. Moreover, studies have been carried out along those lines in the zones west of the Lake (Clément, 2007 and Harimiadana N., 2008). An analysis of a Direct Seeding Group (GSD) in the zone was carried out in 2006 - 2007 (Hanitriharinjaka V., 2007).

Tools were set in place during the first phase of the BVLac project (2003-2008) to enable development of that approach:

• A «plots» and «farms» database through which the farm as a whole can be perceived, and the introduction of cropping system identification codes so that the efficiency of those systems can be compared on a regional and national level. These databases have been operational since 2007.

• Establishment of a network of reference farms (Terrier M., 2008 and Penot E., 2007) in 2007 - 2008 throughout the supervised zones. Those farms, representing all the types of farmers in the zone, including those not adopting the practices, will make it possible to observe, describe and analyse changes linked to the farms. The results of this reference farm monitoring, analysed by OLYMPE farm economics modelling software (INRA/CIRAD/IAMM) (Penot E., 2003), will serve as a basis for proposing improvements or corrections to the farms of the different categories of farmers.

• The organization of «Accelerated Propagation of Innovation» (API) sessions, a self assessment programme (Belloncle, 1990, 2000; Penot E., 2008) to understand innovation processes.

This «farm» approach is complementary to that developed by the GSDM , which is targeting the following objectives: integration of individual and community management of resources, more efficient management, through DMC, of agricultural activities in all the «Upland – Rice Field» landscape units as a whole (biomass flows, labour, animals, hedgerow installation (embocagement), etc.), training of farmers in mastering various DMC scenarios, on their land with the crops of their choice. Such training must enable farmers to understand the agronomic functioning mechanisms of DMC systems (at least 2 to 3 years) and contribute to the organization of village communities (access to bank credit, marketing of agricultural products, input purchases, agricultural equipment, seed production, cuttings, nurseries of bush species for hedgerows, etc.).

In this farm approach context, an operational typology has been constructed based on rice self-sufficiency criteria linked to the types of rice field, the degree of production diversification and, lastly, the type of labour and off-farm activities (Durand C. and Nave S., 2007; Penot E. and operators, 2008)

4 DMC System, a new paradigme for producers

4.1 A diversity of situations calling for a diversity of responses

Various cropping systems, adapted to the different morpho-pedological units with crops selected by the producers, have been identified and proposed:

• Very low-fertility tanety lands on a slope or difficult of access can be developed with forest systems (eucalyptus, essence trees, etc.), or fodder and diversification crops such as low-demand pluriannual crops (pineapple) or annual aromatic plants.

• Slightly more fertile tanety lands, with low-input DMC systems, as the risk is high with this level of toposequence (especially drought).

• Fertile tanety lands, with simple DMC systems favouring low-input systems but allowing a shift to greater intensification.

• Lowlands (bottom of slope, baiboho and rice fields with poor water management – RMME), with more intensive systems due to a much lower risk: at the bottom of slopes annual rainfed systems, or perennial or semi-perennial systems (fruit trees, banana, sugarcane, etc.); on baiboho and RMME, systems including seasonal rice crops (particularly SEBOTA rice) and out-of-season crops have been developed to increase farmer incomes and biomass production for mulch and/or cattle feed in the dry season.

• On irrigated rice fields, improved techniques that are relatively familiar to and mastered by the producers (young plants, improved rice systems (SRA), intensive rice systems (MAFF/SRI), rice-fish farming, etc.) are applied.

Thus, in high-risk zones (drought, flooding, sanding up, etc.) it is essential to propose low input technical solutions due to the major climate risk. Conversely, on very rich baiboho lands not liable to flooding, there should be substantial investment in order to generate major gains, through a particularly worthwhile return on investment.

The final criterion for the choice of cropping systems and crop management sequences is integration of the various farm activities. Thus, agriculture-livestock integration has been developed, firstly to increase fodder availability for the animals by taking advantage in particular of non-cultivated areas to plant fodder and intercrops, and secondly to use animal by-products to fertilize zones with a high production potential, whilst limiting the farmer's expenditure on increasingly expensive chemical fertilizers.

Thus, pure fodder systems (notably grasslands or perennial cover crops under orchards) or mixed fodder/food crop systems are proposed to farmers having an interest in these crops (milk production, draught animals, fattening, etc.).

From initial «off the peg» to the current «made to measure»: description of recommended crop management sequences depending on the toposequence level and on production factors.

Crop management sequences adapted to each type of cropping situation and each type of farmer are proposed by BRL in the zone east of the lake. The main criteria taken into account are as follows: type of land tenure, financial capital, available labour, plot location in the toposequence, soil fertility, farmer preferences, complementarity with animal rearing activities and biomass availability.

4.2 DMC systems on uplands, at the bottom of slopes and on baiboho

4.2.1 Systems producing little biomass (on imported litter, mulch or residues from the previous crop)

Rainfed rice on dead mulch

Rice is the favourite cereal of Madagascan farmers. On a farm scale, rainfed rice on mulch with short-cycle varieties is of great interest as production in irrigated rice fields is often insufficient, or even nonexistent in certain zones supervised by the project. Harvesting is carried out in March and April during the connecting period with high selling prices.

Market gardening and tuber legumes on mulch

Market gardening usually gives good results in DMC systems. The gains in work time obtained by mulching (no hoeing, little watering) make it possible to achieve high profits, especially in the off-season. A complete range of market gardening plants is thus proposed to participating farmers.

Likewise, legume growing on mulch offers the following advantages: reduced hoeing, water savings, easier harvesting, etc.

4.2.2 Systems producing large amounts of biomass

Systems with imported biomass cannot be set up by certain farmers for the following reasons: difficult access to biomass, lack of labour for cutting and transport, high cost of bales. Moreover, such systems are not widespread in the region. An interesting alternative consists in establishing a live cover in the first year (generating income if possible) which will have two

main purposes: soil restructuring and enrichment and creation of biomass for the following crop, alternating primarily with grass-based systems.

Vine legumes in monocultures or combined with maize or sorghum
Once the plot has been «cleaned» this procedure consists in establishing a highly invasive vine legume, such as rice bean (*Vigna umbellata*), hyacinth bean (Lablab purpureus) or mucuna (*Mucuna pruriens* var. utilis). These long-cycle plants (from 5 to 6 months) produce a large amount of biomass, which can be used as mulch for the following crop with, moreover, large quantities of nitrogen fixed by the nodules. This crop management procedure is recommended at all levels of the toposequence with ample organic fertilization on the least fertile soils. Growing with maize makes it possible to combine food production (maize and the legume if the latter produces edible seeds) with biomass production in the plot. The «maize +legume / rainfed rice rotation is the most common.

Stylosanthes guianensis
Stylosanthes guianensis is a perennial plant that is particularly adapted to improving fallow since it has a powerful root system capable of fixing large quantities of nitrogen. Moreover, it can be killed by simple scraping with no need for herbicides, unlike Brachiaria sp. Lastly, it constitutes a very good quality fodder for zebus. Cultivar CIAT 184, which is anthracnose resistant, is now disseminated at Lake Alaotra. The rainfed rice yields obtained after 1 to 2 years of Stylo-based fallow are excellent, even at low fertilizer rates. Stylo can be established alone or combined with a cereal, cassava, Bambara groundnut, etc. to generate income while producing cover.

Systems based on *Brachiaria sp.*
Three species are distributed to smallholders: *Brachiaria ruziziensis, Brachiaria brizantha* (standard species and 'Marandu') and *Brachiaria humidicola*. These forage grasses produce substantial quantities of biomass, even in very low-fertility soils. Their restructuring ability is considerable, they are much better adapted than annual legumes for revegetating highly degraded hillside soils, which are very common in the zone. They make excellent fodders. Brachiaria sp. can be grown in a monoculture or combined with cassava, Bambara groundnut, etc.

Legumes on wild *Cynodon dactylon* cover
The system consists in establishing a tuber or vine legume or any other food legume after controlling Bermuda grass (Cynodon dactylon) with glyphosate. These systems offer the advantage of being usable when opening up spontaneous fallow: tuber legumes give worthwhile yields for very limited work.

Maize on *Arachis sp.* living mulch
This system consists in sowing the maize crop after partial control of the Arachis sp. mulch in strips. Organic and chemical fertilization is then necessary. This system is still not very widespread, as it offers little room for rice and is mainly geared towards dairy farmers (Arachis is a good fodder, maize is a good provender).

4.3 Rice fields with poor water management (RMME)

Rice fields with poor water management, i.e. which do not benefit from controlled irrigation, account for a considerable area at Lake Alaotra (almost 70,000 ha), to which need to be added some of the 32,000 ha of irrigated areas that have yet to be rehabilitated, and in which downstream zones only receive water in a random and partial manner. Over the last 5 years, the farmers of these rice fields have been able to harvest 3 times, with an average interannual yield over 5 years estimated at 1 tonne/ha which, apart from its random nature, remains very

low and not very lucrative. Few precise data on irrigated rice growing and RMME zones have been obtained since the thesis by Ducrot and Garin (1995).

The introduction and dissemination of new versatile SEBOTA varieties that can be grown under either rainfed or irrigated conditions and the first on-farm trials (in 2003 - 2004 by TAFA on the west bank) show that it is possible under certain conditions to achieve high yields (from 3 to 7 t/ha, depending on the level of fertilization) in these random irrigation rice fields. The proposed crop management procedure consists in sowing right from the first rains, so as to start the crop cycle under rainfed conditions and then continue under irrigated conditions, as the water arrives. It is also possible, in places where water is available at the beginning of the wet season, but where irrigation is not provided up to the end of the crop, to transplant the rice to irrigated conditions and continue under rainfed conditions once the water no longer arrives in the plots. Lastly, the «Improved Direct Seeding» technique that is already very widespread on farms at Lake Alaotra, consists in planting pre-germinated seeds on mud.

Conclusion

In fact, each situation (particularly depending on soil type) enables the establishment of several systems, depending on farmer objectives and constraints.

Soil type	Intensification level	Types of systems
Rich tanety soils	All intensification levels	•Intensive cereal-based systems (maize + legume / rice) rotation •Extensive systems based on fodder plants or on spontaneous flora
Poor tanety soils	Low intensification level	•Extensive systems based on fodder plants or on spontaneous flora (rice on long fallow) •Growing of legumes, notably tubers on mulch or spontaneous flora
Colluvial soils (upland) or sandy alluvial soils	All intensification levels	•Intensive cereal-based systems (maize + legume / rice rotation) •Extensive systems based on fodder crops
Upland alluvial soils	High intensification level	•Intensive cereal-based systems (maize + legume / rice rotation) •Intensive rice systems with an off-season (rice/legume rotation or market gardening on mulch in the off-season) •Intensive systems with a one-year Stylosanthes fallow
RMME with access to water in the off-season	Variable intensification level depending on risk	•Intensive rice systems with an off-season (rice/legume rotation or market gardening on mulch)
RMME without access to water in the off-season	Variable intensification level depending on risk	•Intensive rice systems without an off-season •Systems with a one-year Stylosanthes fallow (being tested)

Table 1: Possible crop management sequences applicable depending on the physical environments

In addition, these systems need to be well integrated within each type of farm, taking into account the means of production available, along with livestock activities. Each type of farm can thus benefit from customized advice.

5 Main Results

5.1 Dissemination of the systems

The distribution of the main cropping systems set in place in 2007/2008 on the east bank of Lake Alaotra is presented in table 2.

Today, the so-called «perpetuated» areas, i.e. not abandoned after the first year, amount to around 51% of the supervised areas, i.e. 302 ha (of which 29% in the second year of supervision, 16% in the third year of supervision and around 6% in the fourth year and beyond).

Type / Crop management procedure	Area (ha)	Number of plots	
Rice (all systems combined)	318 (59%)	1561	
Associated cereals	88 (16%)	457	
Tuber legumes	36 (7%)	174	
Associated cassava	33 (6%)	126	
Vine legume monoculture	18 (3%)	113	
Fodder plants	9 (2%)	50	
Erect legumes	6 (1%)	53	
Market gardening on mulch	0.5 (0.1%)	9	
Other	12 (2%)	60	
DMC		520 ha (97%)	2603
RMME		18 ha (3%)	82
Revegetation		176	
Of which		48 ha in year 2 and beyond	
and		20 ha in year 1	
TOTAL Reforestation	15Ha		
TOTAL Pastures improved	61 Pastures		
TOTAL Hedgerows installed	51 km		

Table 2: Area and number of plots completed in 2007/2008 depending on the cropping system type

5.2 Predominant influence of the dates on which DMC type crop management procedures are introduced

The date of rainfed crop establishment is a decisive factor in a context of random rainfall (between 600 and 1500 mm/year) and with large variations in the length of the wet season (between 65 and 130 days) and decadal distribution. Particular attention is paid to the respect of deadlines fixed with the producers before the start of the campaign, particularly for cereal-based systems (rainfed rice and maize). Each year, the yield results are directly correlated to the establishment dates, notably for rainfed rice and maize.

5.3 Yields

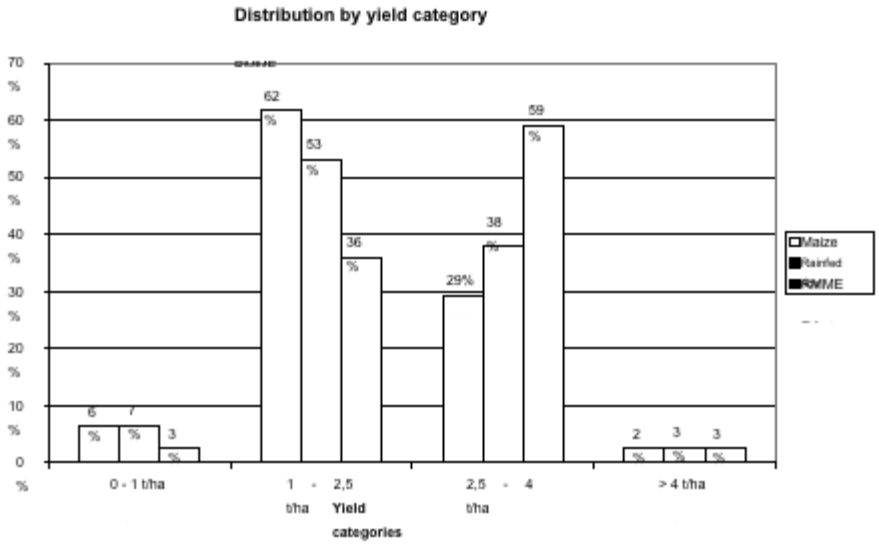
5.3.1 Yields of the main cereal-based systems

The systems are compared with each other on the following basis:

W: with tillage (the first year of direct sowing is in fact an intensified crop on tilled land making it possible to «enter into» direct sowing systems)

DMC Year 1, 2,… : actual direct sowing after year 0 with tillage (direct sowing on mulch)

A stratification common to all the project operators is used: Score 1: 0<Yield<1 t/ha, Score 2: 1<Yield<2.5 t/ha, Score 3: 2.5 <Yield< 4 t/ha, Score 4: Yield > 4 t/ha.



Graph1: Distribution by yield categories (maize, rainfed rice and RMME), 2008

These results come from yield surveys undertaken in all the rice and maize plots, i.e. 1852 plots with no distinction between toposequence levels (graph 4). Of this set of surveyed plots (2857), 2157 were assessed, amounting to a unique frame of reference on Lake Alaotra but also for the whole of Madagascar. The results show satisfactory yields for the rainfed rice crop systems in particular, despite a very short wet season (from 60 to 75 days). On RMME and baiboho, rice varieties of the SEBOTA type reach very good yield levels. For its part, rainfed rice also displays satisfactory yields, whilst maize shows more middling yields.
These satisfactory agronomic results are backed up by early harvests sold at high prices.
Table 3 shows the results depending on the toposequence and on how many years the plot has been under direct seeding.
Yields can be locally very high, up to 7 t/ha in some «perpetuated» plots of rainfed rice and DMC maize, which amount to a technical optimum rarely achieved on average. These maximum yields are always achieved in direct seeding, notably due to a clear improvement in soil quality and better fertilizer use. In terms of minimum yields, they are always lower with tillage than in DMC. These results reveal the impact that DMC can have on managing climate hazards through a buffer effect. In future, it will be interesting to check this strong and, above all, essential hypothesis for producers.

2007 – 2008 season			CV plots	DMC Plots: number of years in DMC					Total
Main crop	Toposequence	Yield/ Nb plots		1	2	3	4	5	
Maize	Tanety	Yield	1 984	2 050	2 142	2 547	2 917		2 055
		Nb of plots	163	57	56	12	1		289
	Bottom of slope	Yield	2 247	2 211	1 444	2 098			2 075
		Nb of plots	22	5	8	4			39
	Baiboho	Yield	2 096	2 481	2 322	3 488	1 723		2 247
		Nb of plots	45	18	9	2	1		75
Mean maize yield			**2 031**	**2 157**	**2 088**	**2 552**	**2 320**		**2 093**
Number of maize plots			**230**	**80**	**73**	**18**	**2**		**403**
Rice	Tanety	Yield	1 947	1 778	1 850	2 657	4 032		1 927
		Nb of plots	232	60	47	8	1		348
	Bottom of slope	Yield	2 156	1 817	2 402	1 862		1 690	2 110
		Nb of plots	71	19	11	2		1	104
	Baiboho	Yield	2 422	2 423	2 399	2 625	2 455	3 550	2 434
		Nb of plots	513	210	89	45	19	2	878
	RMME	Yield	2 737	2 501	2 601	2 457			2 608
		Nb of plots	49	45	14	9			117
Mean rice yield			**2 291**	**2 283**	**2 257**	**2 582**	**2 533**	**2 930**	**2 303**
Number of rice plots			**865**	**334**	**161**	**64**	**20**	**3**	**1 447**

Table 3: Presentation of overall results depending on the main crop, toposequence level and cropping system, and the number of years in DMC (whatever the varieties and fertilization levels)

On average, a large difference in production is found between the tanety and lowland areas; in fact, the chemical and water potential of the latter soils is greater and farmers adapt the level of intensification in their plots to the risk level, which is virtually nil on baiboho. Lastly, overall, a great difference is seen in results (considerable standard deviations) in all the systems, which is a consequence of the heterogeneity of crop management sequences (fertilization level, weeding, etc.).
After an analysis of the detailed data, it can be noted that yields stagnated at identical levels in the systems disseminated in the first year on tilled land over the first three years of cropping. Then, yields rose substantially from the third year of direct seeding onwards (except on RMME; the results need to be meticulously analysed due to the great heterogeneity of situations). The direct seeding techniques therefore seem to show durable action over the medium term with a certain agronomic efficiency from the third year without tillage. Thus, the advantages of DMC systems are therefore not always to be sought in yields, at least in the early years of practice, but rather in better labour productivity (work day optimization) and a durable improvement in performance over time. It is thus noteworthy to see that production levels on tanety lands tend towards those in the lowlands after three or four years of direct-seeding.

5.3.2 Yields of the other main systems
The results for legume crops seem to confirm the durable action of DMC systems over the medium term with a certain agronomic efficiency from the second or third year of direct seeding. In fact, the technical-economic data need to be examined so as to study not only yields but also gross margins and labour productivity.

5.4 Economic analysis

The economic analysis is based on two simple and robust criteria: gross profit/ha per cropping system, and work day optimization, in order, in particular, to compare work profitability on the farm with the opportunity cost of working off-farm. Labour productivity is also used for comparisons from one year to the next, to overcome the high within-year and between-year variability of products.

The calculations concerning these two criteria are done as follows:
The gross margins with hired labour (total labour times are converted into intermediate consumptions at the price of local labour) enable us to compare crops and crop management sequences for their profitability. These indications are especially useful for large farms using mostly hired labour.
WDO or Work Day Optimization, enables us to compare farmers' gains with the opportunity cost of hired labour and with other economic activities. These indications are more rather to the analysis of smallholder family agriculture (in this case, the costs of partial outside hired labour are included in the intermediate consumptions, which is rare in the case of the farmers supervised by BRL).

In our evaluations, we considered the average yields and the average product sales prices at harvest time (on the local markets).

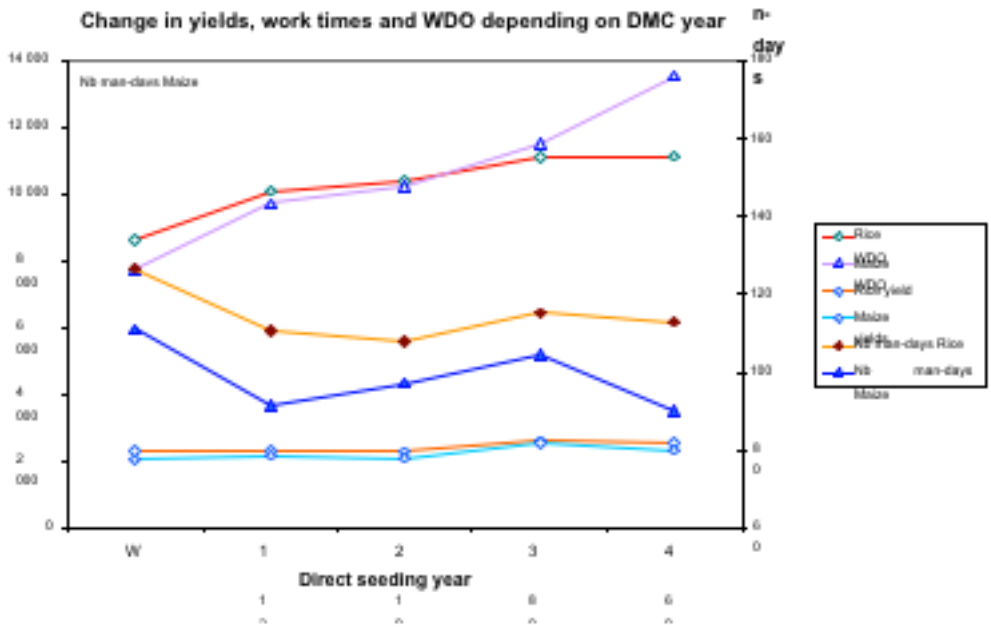
5.4.1Gross margin per hectare with hired labour
This representation is of particular interest for large-scale farmers not taking part in farming operations and privileging the margin and the optimization of work times.

The first conclusions show that the most lucrative systems are seasonal market gardening systems generating gross margins over MGA 1,500,000 per hectare. However, substantial labour availability and technical skills are needed for those adopting these crops, often grown on a few ares. Then come the cassava-based systems but whose cycle is astride two seasons, hence resulting in lower land productivity (MGA 1,500,000 per hectare), then the cereal-based systems: maize (combined with an erect legume with limited growth MGA 1,000,000, with a vine food legume MGA 600,000 and a legume cover crop MGA 570,000) and rice (MGA 800,000). Lastly come the tuber legume systems (groundnut MGA 600,000, Bambara groundnut MGA 450,000) and erect legumes (bean – soybean MGA 300,000). However, the bean-based systems offer the advantage of being short-cycle and thereby ensuring better land productivity in the very short term.

5.4.2 Work Day Optimization
The first conclusions show that the most lucrative systems are DMC rice systems for which the overall WDO values are between 7,000 and 10,000 MGA/day's work compared to an opportunity cost that varies from 2,500 to 3,000 MGA/day's work, followed by the maize-based DMC systems (from 8,000 to 16,000 MGA/day's work). Then come the tuber legume systems, which are low risk and fairly lucrative (from 4,000 to 9,000 MGA/day's work), then bean. The marginal systems such as market gardening on mulch are delicate but highly lucrative.

It is therefore logical to see that Lake Alaotra farmers favour cereal crops, especially on high-potential soils. However, it is found that tuber legumes provide a good return on labour, even on poor soils. Beans make good use of the land but provide less return on labour.
As for plot perpetuation, graph 2 shows a clear increase in labour productivity over the years of DMC practice. Take for example the rainfed rice-based systems (on upland zones) and associated maize. In the first year of direct seeding it is possible to see i) a drop in labour costs

particularly involving the suppression of tillage and reduction in hoeing time, and ii) a certain stagnating of yields (for the same level of fertilization), hence a strong increase in WDO. The same applies for the other cropping systems, as shown in table 4.



Graph 2: Yields, work times and WDO depending on how long the plot has been in DMC (cereal-based systems, 2007/2008 season)

			Plot DMC year					
Main crop 2007/2008 season	**in MGA/ ha**	**Mean Direct See-ding**	**W: Soil tillage**	**1**	**2**	**3**	**4**	**5**
Cassava	Mean WDO	**23 802**	**17 483**	23 706	23 995			
	Population	**9**	**33**	6	3			
Rice	Mean WDO	**10 356**	**8 648**	10 123	10 415	11 132	11 162	11 377
	Population	**567**	**851**	327	155	63	19	3
Maize	Mean WDO	**10 188**	**7 757**	9 739	10 245	11 545	13 571	
	Population	**172**	**225**	79	73	18	2	
Groundnut	Mean WDO	**9 152**	**7 583**	8 913	9 438	9 779	9 535	
	Population	**45**	**46**	26	16	2	1	
Bambara groundnut	Mean WDO	**7 800**	**6 834**	7 812	7 788			
	Population	**10**	**51**	5	5			
Bean	Mean WDO	**7 464**	**5 034**	7 387	7 429	7 762		
	Population	**13**	**27**	5	6	2		
Cowpea	Mean WDO	**3 740**	**3 471**	3 480	4 493	3 263		
	Population	**17**	**58**	9	5	3		

Table 4: WDO per cropping system and per year of DMC practice for the 2007/2008 season

To sum up, it can be seen that:
Work times decrease in the first year without tillage then increase again (labour intensification), then drop substantially from the fourth year of direct seeding onwards.
Yields stagnate in the early years then increase clearly from the third year of direct seeding onwards.
Consequently, the WDO increases throughout the plot perpetuation process in direct seeding.
This information therefore enables us today to provide the supervised producers with better advice:

- On uplands, cereal crops and notably rice, should, were possible, be avoided in the early years of direct seeding, to the benefit of less demanding and lower risk crops, such as tuber (low risk AND good gross margins and work day optimization),
- Heavy fertilization is not recommended in the early years of direct seeding, so as to limit weed invasion in the plot but also financial risks induced by climate variations.
- However, from the third year of direct seeding onwards, the crop management sequences can be more intensive due to i) the depressive effect of mulches on weeds, ii) a reduced climate risk due to the buffer effect of the mulch and accumulated organic matter, iii) a much lower financial risk. Consequently, fertilization levels should be increased and labour can be intensified. In addition, work time savings should make it possible for each household to cultivate larger areas.

Let us now concentrate on the WDO analysis depending on the number of years the plots have been in DMC and their position in the toposequence based on the following typology: uplands (tanety), colluvial soils at the bottom of slopes, emerged alluvial soils (baiboho), and rice fields with poor water management (RMME).

It is found that Work Day Optimization is always greater in the lowlands than the uplands. This difference can be explained by the positive water resource gradient throughout the toposequence. Likewise, there is a substantial fertility gradient, with the finest elements being dragged from the uplands and redeposited in the much more fertile lowlands. These lowlands are tokens of security and can approach the risk levels found in irrigated zones. Despite that, year after year, the WDO of DMC systems on uplands tends to approach that of the lowlands, proving yet again the merits of direct seeding over the medium and long terms. It should be noted that baiboho soils can be used to grow maize and offer excellent Work Day Optimization.

	Toposequence	Plot DS year			
		W	1	2	3
Maize	Tanety	7 383	9 121	10 217	10 206
	Bottom of slope	8 528	11 691	8 730	13 526
	Baiboho	8 819	11 120	11 765	15 620
Mean WDO for maize		**7 757**	**9 739**	**10 245**	**11 545**
Number of plots		225	79	73	18

Table 5: WDO results for maize for 2007/2008 depending on the position in the toposequence and the number of years the plot has spent in direct seeding

	Toposequence	Plot DS year				
		W	1	2	3	4
Rice	Tanety	7 444	7 619	8 923	11 659	
	Bottom of slope	8 527	6 832	9 893	10 420	
	Baiboho	8 978	11 095	10 839	11 049	10 559
	RMME	11 169	10 160	12 904	11 228	
Mean WDO for rice		**8 648**	**10 123**	**10 415**	**11 132**	**11 162**
Number of plots		851	327	155	63	19

Table 6: WDO results for rice for 2007/2008 depending on the position in the toposequence and the number of years the plot has spent in direct seeding

Intensification of the lowland zones therefore appears as a priority in the allocation of production factors, notably financial. Conversely, it seems preferable to develop tanety areas much more extensively. It will be appropriate only to intensify crops on tanety after several years of direct seeding (at least 3), by which time the risk level is much lower.

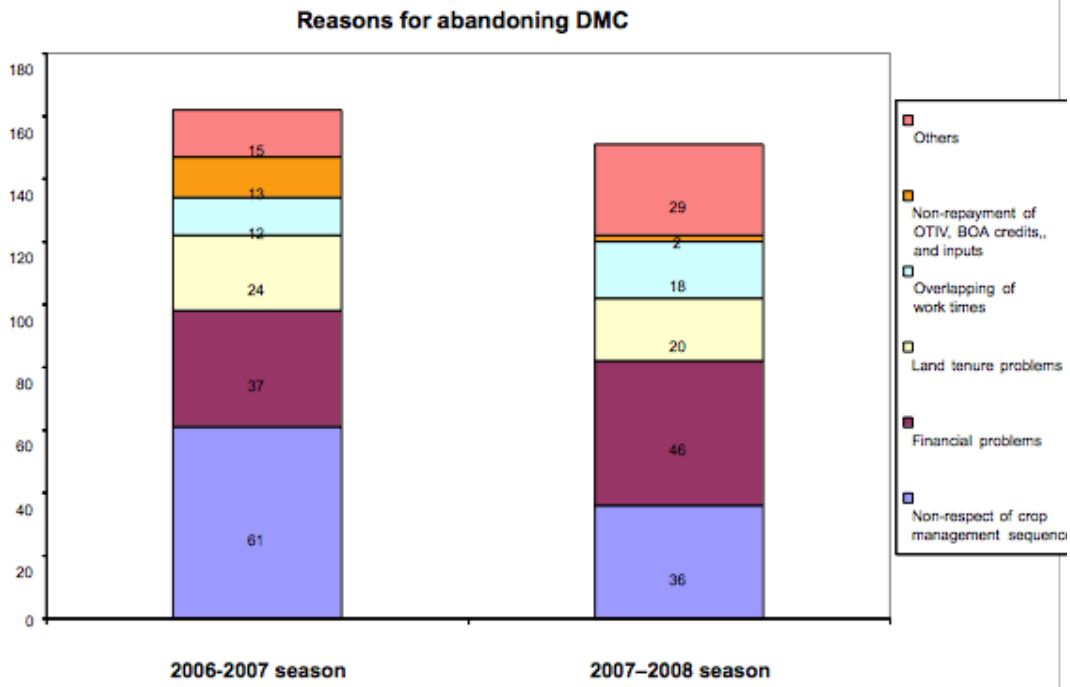
Risk is a central element in managing production factors for most of the local farmers. Intensification is limited by climate risk, which is substantial around the lake, and economic risk, created by high price volatility between and within years (Houssein S., 2007; Rakotondrazafy H., 2007; Ramambasoa T., 2007). These two factors induce a real risk for taking out credit (Oustry M., 2007). However, various types of credit (individual, collective with co-surety, etc) are available but with very middling results.

These risks are true brakes on intensification. Farmers favour extensive or low-intensity systems on the most degraded soils in the first 3 or 4 years of DMC. It seems that the demand for intensification occurs after the fourth year of direct seeding when, once the innovation is established (and direct seeding constitutes in that respect a true change in paradigm), confidence is established and the results are decisive, the farmer wishes to move on to a true increase in productivity through an intensification of chemical fertilizers and labour. However,

the overall priority remains a strong demand for organic fertilization. The development of veritable manure and compost sheds satisfies that strong demand, strengthening the need for true agriculture-livestock integration.

6 Analysis of abandonment rates

As each year, some farmers have opted not to continue practising agro-ecology. Thus, for 2007–2008, 26.4% of farmers abandoned DMC in one or more plots and 28% of the supervised areas were not perpetuated. In 2006-2007, the results showed that 39% of farmers had abandoned DMC in one or more plots and 31% of the supervised areas had not been perpetuated, indicating a certain tendency towards stabilization of the pool of supervised farmers.
Three types of main reason seem to explain these failures: i) reasons linked to adaptation of the techniques (36% abandonment) such as not respecting the crop management sequence (24%) or overlapping of work times (12%), notably in zones predominated by irrigated rice fields such as in the southeastern valleys; ii) economic reasons (32% abandonment) such as lack of cash-flow (30%) along with the repayment of campaign credits during the off-season (around 2%) and iii) land tenure reasons in 13% of cases.



Graph 3: Reasons for abandoning non-perpetuated areas (in hectares)

The areas abandoned for technical reasons have substantially decreased and, in 2008, reached the level of areas abandoned for financial reasons, with a strong increase in the price of inputs and labour. In terms of land tenure, there seems to have been the encouraging beginnings of stabilization. The recent establishment of land tenure offices has probably had something to do with that phenomenon. Lastly, today credit seems to be well understood and taken on board by the farmers, with only 2% of the areas abandoned by farmers having been so for credit repayment reasons. Lastly, it should be noted that, due to the short wet season and violent climatic episodes, the areas abandoned due to overlapping work times (12%) and climatic incidents (5%) considerably increased over the 2007-2008 season.

It should be noted that the technique of analysing abandonments by the cohorts method was developed by Vakinankaratra in 2007 (Randrianarison N.) and is due to be extended to Lake Alaotra in 2009.

7 Growing interest of farmers in these locally adapted techniques

In 2007-2008, the total areas supervised increased substantially, notably in the zone north of the lake. The dissemination trend in that zone is remarkable (+26% in area and +12% in adopting farmers). In fact, the farming systems in the zone are totally dependent upon the sustainable development of uplands with relatively fertile soils as the vast majority of those farmers do not possess irrigated rice fields. As regards the zones located near irrigated areas (valleys in the Southwest), after showing disappointing results in 2005-2006, they exhibited a very positive outcome for 2007-2008 with twice as many areas and a strong increase in the number of supervised adopting farmers (+60%), which is mainly due to better matching of rainfed-irrigated cycles and some very persuasive demonstrations on baiboho.
In 2007-2008, the total number of supervised areas increased substantially, by more than 40% compared to 2006-2007. The number of adopting farmers also rose substantially by more than 22%. The technical-economic results obtained showed a growing interest of farmers in the DMC systems on tanety and in RMME zones, which are highly dependent upon increasingly random rainfall making agricultural activities particularly risky, but also in highly suitable zones, such as the baiboho zones. Only farmers who made serious mistakes in applying the recommended crop management sequences did not make a return on their investment. Non-respected sowing dates particularly had a very strong impact on the production levels achieved, especially as the cropping season was very short.

This progress highlights the need to propose cropping systems adapted to farmers' objectives depending on the degree of risk they judge acceptable. For instance, crops intended for animal feed (cover crops such as M. pruriens, E .coracana, improved fallow based on *S. guianensis* or Brachiaria sp.) which help to increase farm income and optimize animal production and which are very good previous covers in DMC systems, are increasingly favoured by local producers, confirming the merits of an approach with agriculture-livestock integration.

The technical results for the 2007–2008 season show a generally positive trend despite the considerable constraints specific to this season: i) unlike last year, the overall rainfall was normal but geographically poorly distributed (from 615 mm in the North to 1065 mm in the valleys of the Southeast). Moreover, the wet season was concentrated in two to three months (thus, some zones had to cope with periods of drought, but also flooding and exceptional damage such as hail or cyclones); ii) the late release of credit taken out by the farmers with the BOA, which had a negative impact on yields (late inputs, late hoeing, etc.).
In agronomic terms, the technical grasp of the farmers is improving year after year, as proved by the results obtained during this season, revealing substantial innovation capacity.

The «maize + legumes / rainfed rice» cropping systems cover a large proportion of the areas developed in DMC. Indeed, the income derived from them is substantial, right from the first year of development, and rice remains a priority for many farmers. Likewise, the low input systems based on *S. guianensis* offer fine prospects for development. In the lowlands there is a strong advance of out-of-season vetch-based cropping systems, in monocultures or combined with market garden crops. These systems, developed between farmers and BRL technicians, show the farmers' great capacity for adaptation and development, in collaboration with dissemination staff. The same applies for the cassava + Vigna radiata + *Stylosanthes guianensis* systems currently being developed.
Conversely, some systems are having trouble developing in the smallholder environment: direct sowing on Cynodon dactylon spontaneous flora due to insufficient biomass (dry season

pastures), seasonal market gardening on *Brachiaria ruziziensis*, which the farmers refuse to kill due to lack of fodder, maize on live mulch preventing the introduction of rice into the system, etc. Lastly, it is interesting to see that tillage has become a last resort if the cover is not successful (invasion by weeds, especially grasses) or after a cropping incident (fire in the cover crop, flooding, sanding up, etc.).
Diversification of the systems is therefore necessary, but it must be rational for better risk management (climatic, phytosanitary, economic, etc.) with better integration of agriculture and livestock activities (systems based on fodder plants such as Brachiaria or Stylosanthes). For instance, systems based on Stylosanthes, combined notably with maize and cassava are beginning to develop slowly but surely, corresponding to a strategy of redeveloping highly degraded lands with extensive systems with improved fallow (without production) and appropriate rotations (cereals/legumes). The references acquired by the project in the Lake Alaotra region in the last 5 years by way of complete and utilized databases provide an understanding of the dynamics under way and the innovation process.

Overall conclusion

A differentiated analysis of the margins achieved depending on the cropping systems used (varieties, fertilizer rates applied, number of years the plot has spent in DMC and level in the toposequence) provided us with information enabling us to improve dissemination quality for the different technical and organizational aspects (including credit).

The results presented here confirm a significant change in the income derived from «perpetuated» plots. The farm approach makes it possible to understand farmer strategies and what determines the allocation of production factors, so as to propose a range of crop management sequences adapted to each situation (financial, land tenure, social and human, existence of livestock activities, or off-farm activities), as indicated in table 7. This work should lead to the elaboration of precise technical-economic frames of reference for farmers and funding organizations (BOA, OTIV, etc.). Alongside these technical actions, a more global geographical approach in the project zones has been developed in order to take into account the «watershed» dimension of the project and the interaction between toposequences. Thus, land development plans have been drawn up in a few villages for the efficient organization of rural and agricultural land use planning.
Development of these DMC type systems cannot be integrated without taking into account services to agriculture, a need induced by the true change in paradigm that the adoption of DMC brings about: preserving quality technical information, promoting manure and compost shed techniques to limit the use of chemical fertilizers that have become too scarce and too expensive, maintaining a level of social cohesion in the groups for access to credit with co-surety (limited in time), product marketing and market information, etc.

Lastly, agriculture-livestock integration remains a priority for ensuring the transfer of fertility, guaranteeing outlets for the use of certain cereals (maize), diversifying income and enabling a balanced development of land and of practices between zones devoted to agriculture and forestry, pastures and protection/conservation.

Cropping system	Origin	Advantages sought	Constraints	Dissemination rate	Future prospects
Rice/vetch + bean/rice/etc.	TAFA then farmers + technicians	Highly lucrative systems that are easy to set up	Roaming animals	+++	+++
Systems on *Stylosanthes guianensis*	TAFA then farmers + technicians	Extensive but highly lucrative systems Fodder production	Need for a year of fallow for an optimum result	+++	+++
Maize + legumes/ rice	TAFA	Highly lucrative intensive systems	Good quality soils Labour and input intensive Fairly high risk level	+++	+++
Maize + legumes/ tuber legumes	TAFA + farmers	If the farmer's resources are limited, enables tuber legume cultivation without any great investment	A cover crop has to be established with the tuber legume, at the risk of not generating biomass	++	++
Systems on Cynodon dactylon	TAFA	Extensive and lucrative systems	Herbicide use Lack of available biomass	+	++
Systems on living mulch	TAFA	Extensive and lucrative systems Mainly for livestock breeders	Herbicide use Little room to grow rice	-	++
Complex systems	TAFA	Highly productive in products and biomass	Too difficult to implement	-	-

Table 7: Future prospects for DMC systems around Lake Alaotra

Bibliography

Belloncle G. 2003. Sept priorités pour développer Madagascar. Foi et justice.

Clément J. 2007. Etude des stratégies d'acteurs sur la sécurisation foncière et la mise en valeur du territoire : le cas de la commune d'Amparafaravola. Lac Alaotra, Madagascar. ENESAD, Dijon.

CIRAD, GSDM, SDMad et TAFA. Intérêts et contraintes de mise en culture des nouvelles variétés de riz brésiliens poly-aptitudes appelées SEBOTA.

Colleta M., Rojot C. 2006. « Caractéristiques agraires de deux zones du lac Alaotra, conditions et impact de l'adoption des systèmes de semis direct sur couverture végétale ». INA PG, CIRAD, BRL dissertation, Madagascar.

Devèze. 2008. « Défis agricoles africains » ; Évolutions des agricultures familiales du Lac Alaotra (Madagascar). Karthala, Paris.

Domas R, Andriamala H. 2007, 2008. Rapports de campagne de saison BRL 2006 – 2007, 2007 – 2008 et de contre-saison 2007.

Domas R, Andriamala H. 2007, 2008. Rapports de synthèse BRL 2007 et 2008.

Durand C., Nave S. 2007. « Etude des dynamiques agraires et des stratégies paysannes dans un contexte de pression foncière, Lac Alaotra ». SUP-AGRO-IRC dissertation, CIRAD, Madagascar.

Ducrot R. 1996. Régulation d'une production en situation d'incertitude et de fortes contraintes : exemple des systèmes rizicoles du lac Alaotra (Madagascar). INA Paris Grignon / CIRAD.

GSDM. Manuel SCV Madagascar Vol. I, II, Vol III. Stratégie du GSDM pour la diffusion des techniques agro-écologiques.

Hanitriharinjaka V. 2007. Etude d'impact sur l'intérêt de l'action collective type GSD/ACCS sur les revenus agricoles, University of Tamatave.

Harimiadana N. 2008. Aménagement et gestion de l'espace : le cas des ZGC d'Ankalampona, d'Ampasika et d'Ampasindava. ESSA / University of Antanarivo.

Houssein S. 2007. Etude de la filière tomate au lac Alaotra. ESSA/Université de Antanananarivo, Madagascar. (Co-encadrement avec Tiana Rahaingoalison, consultant BV Lac commercialisation.

Oustry M. 2007. « Analyse des causes de non remboursement des crédits au Lac Alaotra : Impact sur l'accès au crédit et sur le fonctionnement des ACCS ». ESAT 1. SUPAGRO / IRC.

Penot E. 2008. Document de travail du PROJET BV-LAC N° 4 : Mise en place du réseau de fermes de références avec les opérateurs du projet. Document de travail projet BV Lac / AFD.

Penot E. 2007. Appui au volet « professionnalisation des organisations de producteurs » du projet BV Lac au lac Alaotra : mission août 2007 : mission d'appui auprès de la cellule du projet, mise en place du réseau de fermes de références avec les opérateurs du projet. CIRAD.

Rakotondrazafy H. 2007. Etude de la filière pomme de terre au lac Alaotra. ESSA/Université de Antanananarivo, Madagascar. (Co-encadrement avec Tiana Rahaingoalison, consultant BV Lac commercialisation.

Ramambasoa T. 2007. Etude de la filière maïs au lac Alaotra. ESSA/Université de Antanananarivo, Madagascar. (Co-encadrement avec Tiana Rahaingoalison, consultant BV Lac commercialisation.

TAFA. 2001. Projet de diffusion de systèmes de gestion agrobiologiques des sols et des systèmes cultivés à Madagascar, Rapport de campagne 2000/2001 et synthèse des 3 années du projet, ONG TAFA – ANAE – CIRAD, AFD.

Terrier M. 2008. Mise en place du réseau de fermes de références dans la zone d'intervention du projet BV/Lac, Lac Alaotra, Madagascar : Méthodologie, conventions et règles d'utilisation. CIRAD / SCRID / UMR Innovation. Mémoire de césure.

Randrianarison N. 2007. « Diagnostic agraire et mise au point d'une méthodologie de suivi et d'analyse des succès et abandons des systèmes à base de semis direct sous couverture végétale (SCV) : cas du fokontany d'Antsapanimahazo – Madagascar. Professional MSc in economic sciences. University of Montpellier I / TAFA / CIRAD.

TAFA. Rapports TAFA Lac Alaotra, 2005, 2006, 2