1.3 FIVE YEARS OF ADAPTATIVE RESEARCH FOR UPLAND DMC BASED CROPPING SYSTEMS CREATION IN CAMBODIA

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Introduction

On the red and black basaltic oxysoil of Kampong Cham Province (Cambodia, # 105°00 East, 12°00 North), farmers have a long term tradition of market oriented upland annual crops productions; in Chamcar Loeu district, pulse species (Mungbean -Vigna radiata-, Soybean) were already grown on recent forest reclaimings in the early 50’s (Delvert, 1954); while some small hills, neighbouring large rice plains in Ponhea Krek district were reclaimed around 1930 (old farmers declaration). Almost totally given up during war times (70’s and 80’s), upland cultivations restarted in the 80’s and early 90’s with the progressive stoppage of guerrilla operations in the region. In the recent years, farmers focused mainly on Soybean and more recently on Cassava; Corn, Mungbean, Sesame, Groundnut remaining secondary crops.

Traditional cropping systems are based on disc plowing and face increasing agro-technical problems leading to a decrease of the economic performances, partly hidden by the recent increase of the agricultural commodities prices in 2008.

This trend weakens the small and medium farms which are not able to afford the conversion to good quality rubber cultivation and condemns the larger units to progressively develop perennial crops’ mono-cropping (Rubber, Banana).

In response to this general statement, the Ministry of Agriculture, Forestry and Fisheries of the Royal Government of Cambodia has initiated, with the support of the AFD and CIRAD, a research and development programme using the Direct seeding Mulch based Cropping systems (DMC) as a way to create and propose sustainable and diversified cropping systems to farmers.

This paper aims to describe the overall methodology and the stages leading to the creation and technico-economic validation of diversified DMC, addressing various farmers’ possibilities and markets’ opportunities. Several developed systems are described in details and further orientations in DMC design are proposed.

All this initial phase of transferring and adapting DMC to Cambodian agriculture conditions has been largely organized around a south to south transfer of the technologies developed by CIRAD researchers in Brazil (L. Séguy and S. Bouzinac).

Physical context and main farmers' reference cropping systems

Climate and consequences on crops successions arrangement

Climate of the central plain of Cambodia is simple and can be summarized as follow in the **figure n°1**.

Farmers experience the climate as highly changeable from year to year; most of them consider the first months of the rainy season, March-May, as a risky time for agriculture. Rainfalls usually become more regular in July, even if decades with rains deficit are still likely to occur up to the end of July. The date of the last significant rainfalls varies also a lot from year to year, between mid October to end of November. This figure drives the crops choices and sowing dates in order to buffer these climate's hazards, for both reference systems of farmers and new designed DMC as summarized in the Table I. below:

Table I. Crops successions driven by climate risk management

	1st part of the rainy season: April - June	2nd part of the rainy season: July-November
Farmers reference	Short cycle with drought tolerant crops like Sesame, Mungbean	Main cycle of Soybean to be harvested end of October-early November
DMC	Biomass production with BPsc or BPlc	Soybean harvest # 30/10 Rice Harvest # 5/11 Corn Harvest # 10/11 … resilient with a rain stoppage mid October

BPsc: Short cycle bio pump (see below)
BPlc: Long cycle bio pump

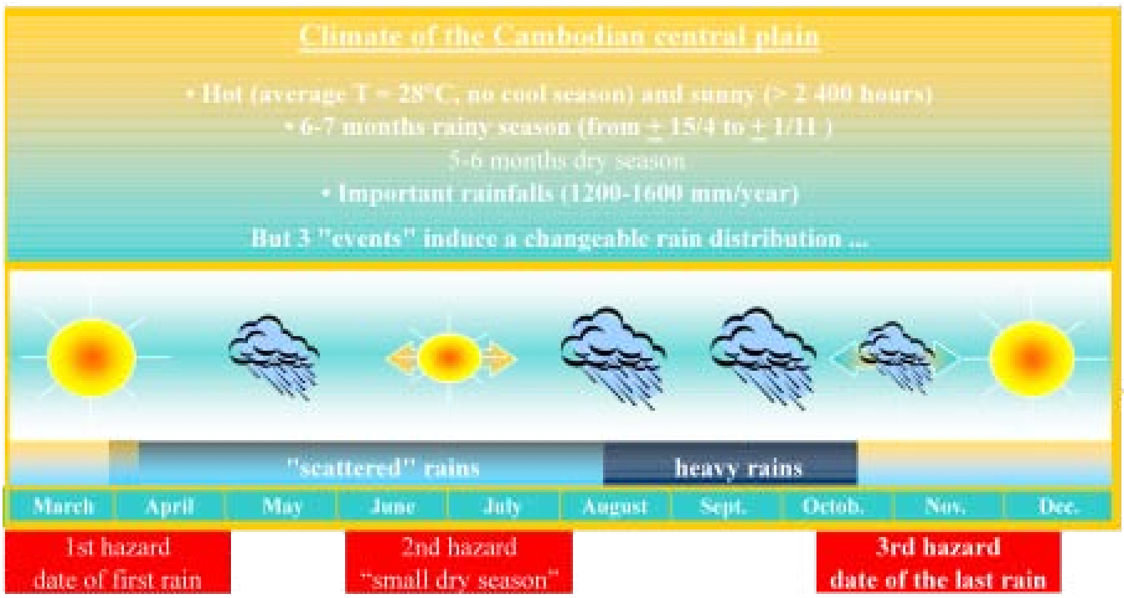


Figure 1 : A changeable rains distribution

Soil

Main physical and chemical properties of the "red soil" are presented in the table II., the first (Sla) is a recent forest reclaim (around 10 years) while the second (Sahakreas) is an old cultivation area (reclaim in the 50's). Complementary samplings realized in some others plots, under various crops with contrasted plot's history confirm the following general trends:

(1) Deep and clayey soil profile

(2) Acid and unsaturated ECC with moderate to high level of saturation by Al

(3) Medium to high OM contains combined with clay (type?) provides high ECC

(4) Medium to v. high Pexch contains, likely ling to basalt parental ma

(5) Macronutrient: deficiency in Ca, relatively higher contains in Mg, important variations for K availability (from very low < 0,05 to very high > 0,40 cmol/dm3)

(6) Micronutrient: high level for all main micronutrients (Zn, Mn, Cu,Fe) except for Bore

Black soils, also developed on basaltic substratum, are chemically close to red soil but, due to shallower water table which have induced creation of ironstone bank, they usually present many gravels in the profile.

Low
Very low

		Matrice Memot Sla				Matrice Chamear Loeu Sahakreas				
Depth	cm	0-10	10-20	20-40	40-60	0-10	10-20	20-40	40-60	
% Sand		5,8	4,7	3,9	4,1	7,9	7,3	6,0	5,5	
% Silt		13,8	13,5	12,9	12,9	12,7	14,1	13,6	12,1	80% CLAY
% Clay		80,5	81,8	83,3	83,3	79,4	78,6	80,4	82,4	
C organic	g/dm^3	26,4	20,9	16,8	13,9	16,3	14,7	11,8	8,2	Medium to high C conta
Organic matter	%	5,0	4,0	3,2	2,7	3,1	2,8	2,3	1,6	
pH CaCl2		4,7	4,5	4,4	4,5	4,3	4,3	4,4	4,4	Low to very low pH
H + Al	cmolc/dm^3	7,11	7,36	6,95	6,59	9,12	9,32	8,34	7,88	
Al exchangeable	cmolc/dm^3	0,41	0,60	0,73	0,64	1,67	1,66	1,42	1,42	
Ca exchangeable	cmolc/dm^3	2,63	1,83	1,70	1,43	1,67	1,59	1,71	1,68	Low Ca contain
Mg exchangeable	cmolc/dm^3	1,13	0,90	0,61	0,85	1,40	1,32	1,19	0,97	Medium to high Mg conta
K exchangeable	cmolc/dm^3	0,35	0,26	0,15	0,16	0,08	0,05	0,03	0,03	V. low (in CL) to v. high K e
P exch.	mg/dm^3	7,2	5,4	4,4	6,5	27,3	26,8	31,7	37,5	Low to high Pexch conta
CTC at pH 7,0	cmolc/dm^3	11,2	10,3	9,4	9,0	10,6	11,1	10,9	9,3	
CTC effective	cmolc/dm^3	4,5	3,6	3,2	3,1	4,8	4,6	4,4	4,1	
Sat. for bases (V)	%	36,5	28,8	25,3	25,5	53,3	43,1	27,2	54,3	Low saturation rate by base
Sat. for Al (m)	%	9,6	17,3	25,5	25,2	34,9	36,3	32,8	34,9	High degre of saturation by
Sat. for Ca	%	23,3	17,7	17,2	14,8	31,7	22,2	15,8	36,6	
Sat. for Mg	%	10,1	8,7	6,5	9,1	20,4	20,0	11,1	16,9	Unbalanced saturation by b
Sat. for K	%	3,1	2,5	1,6	1,6	1,2	0,8	0,3	0,8	pronounced relative deficien
Ratio Ca/Mg		4,2	2,1	2,8	1,7	1,2	1,3	1,5	1,9	K and Ca compared to M
Ratio Ca + Mg/K		11,3	11,2	16,3	18,2	40,3	56,7	91,7	114,0	
B	mg/dm^3	0,28	0,21	0,19	0,17	0,23	0,20	0,12	0,07	Pronounced deficiency in
Cu	mg/dm^3	1,60	1,35	0,91	0,99	1,60	1,53	1,03	0,70	V. high contains in all other
Fe	mg/dm^3	38	30	26	26	61	59	43	32	micronutrients
Mn	mg/dm^3	166,8	119,9	87,1	72,8	82,2	68,4	47,2	30,9	but high P & OM contains may aff

Table II : Soil analysis of 2 red basaltic oxysoil plots
Main farmers reference cropping systems for annual upland crops production

Up to 2008, farmers practises for upland annual crops presented small diversification; they were dominated, (1) on red soil by an annual succession of Sesame and Soybean, each crops preceded by a shallow disc plowing and, (2) on black soil, by a monocropping of Cassava with long cycle of 9 to 10 months (planting in April – Harvest in January-February), with similar soil preparation.

Crop sequence and economical models

These systems rely on a mechanical disc plowing accessible through "contractors" and do not use any fertilizers (manure nor mineral); rarely, some insecticides applications are done on Sesame and Soybean. The Table III and Table IV present the operational sequences and their costs (price 2008); these costs allow, combined with farm gate prices of the products, to set up simple economic models to assess the gross profit margins of these reference cropping systems.

Sesame crop -sometimes replaced by Mungbean (Vigna radiata)- is used to face the risky rain conditions of the first part of the rainy season. Sesame's results depend mainly of the initial rains (establishment of the plants population); a first remote rainfall (e.g. followed by 7-8 dry days) can frequently induce re-sowing (in the "model" 1,5 sowing/y); when a late arrival of rains postpones the harvest date and can force the farmer to plow the plot before the Sesame's harvest in order to sow the Soybean, the main crop of this year succession, on time.

Prices paid to farmers were quite stable during the last 3 years and relatively high (when compared with international price): Sesame were paid to farmers around 900 USD/t and Soybean at 400 USD/t in 2008.

Table III : Crops management, cost and profit margins of the reference cropping system Sesam / Soybean x PLOW

		Crop management sequence			Cost (US $ / ha)	
		Task	Method	Labour organization	Labor	Input
Sesame	February - March	Plowing	Mechanical disc plow	Contractor	25	
	March (end)	Furrow drawing	Animal draught plow	Contractor	15	
		Sowing	Manual seeder	Family or hired lab. force	6 lab.day/ha** - 18	10,5
	May	Weeding	Manual (hoe)	Hired labour force	15 lab.day/ha - 45	
	June (end)	Harvest	Manual	Hired labour force	10 lab.day/ha - 30	
		Treshing	Mechanical fix tresher	Contractor	2 US$/100 kg	
		Post harvest	Transport, drying …	Family or hired lab. force	2 US$/100 kg	
Soybean	June (end)	Plowing	Mechanical disc plow	Contractor	25	
	July	Sowing	Mechanical sow	Contractor	15	75
		Weeding	Manual (hoe)	Hired labour force	20 lab.day/ha - 60	
	August	Weeding	Manual (hoe)	Hired labour force	15 lab.day/ha - 45	
	November	Harvest	Manual		15 lab.day/ha - 45	
		Treshing	Mechanical fix tresher	Contractor	2 US$/100 kg	
		Post harvest	Transport, drying …	Family or hired lab. force	2 US$/100 kg	

** 2 sowing requested 1y/2

$$\mathbf{GM}_{\text{sesame/soybean}} = \mathbf{0{,}86 * Y}_{\text{sesame}} + \mathbf{0{,}36 * Y}_{\text{soybean}} - \mathbf{408}$$

GM = gross profit margin (US $/ha), Y = Yield (kg/ha)

The key parameter for the economical results of a Cassava crop is the farm gate price which can vary a lot from year to year: between 2000 and 2007, the Cassava farm gate price was comprised between 25 and 80 USD/t (for peeled, sliced and sun-dried tubers), showing a favorable trend during the period 2005-2007 (between 60 and 80 USD/t), before to soar in 2008, reaching 175 USD/t. This recent prices' improvement strongly stimulates Cassava extension, to the detriment of Soybean, especially on the degraded upland black soil area of Dambe and Ponhea Krek districts.

On all these systems, farmers experience progressive yields decrease, partly hidden by inter-annual climate variations. In the recent years, profit margins have been also seriously reduced by the pronounced raise of the labor price, passing from 1,25 USD/day in 2004-05 to around 3, USD/day in 2008.

Table IV Crops management, cost and profit margins of the reference cropping system Cassava x PLOW

		Crop management sequence			Cost (US $ / ha)	
		Task	Method	Labour organization	Labor	Input
Cassava	February - March	Plowing	Mechanical disc plow	Contractor	25	
	April (end) - May	Planting	Manual	Fam. &/or hired lab. force	15 lab.day/ha - 45	
	June	Weeding	Manual (hoe)	Fam. &/or hired lab. force	20 lab.day/ha - 60	
	July - August	Weeding	"	Fam. &/or hired lab. force	20 lab.day/ha - 60	
	January +1	Harvest	hand pulling …	Fam. &/or hired lab. force	25 lab.day/ha - 75	
		Plot clearing	"wood collect" …	Fam. &/or hired lab. force	5 lab.day/ha - 15	
		Post Harvest	Manual peeling, cut, dry	Fam. &/or hired lab. force	10 US$/t of dry C.	

$$\mathbf{GM_{cassava} = (a - 0{,}01) * Y_{cassava} - 280}$$

GM = gross profit margin (US $/ha), Y = Yield (kg/ha), a = farm gate price for dry-peeled cassava (in US $/kg, high annual variation)

Table V. Yields (kg/ha, 14% humidity) on Red and Black soils of the reference cropping system Sesame/ Soybean x PLOW

		2004		2005		2006		2007		2008	
		Ses.	Soy.	Ses.	Soy.	Ses.	Soy.	Ses.	Soy.	Ses.	Soy.
Degraded Red Soil (Sahakreas)	F0	305	340	-	725	170	290	-	410	-	330
	F1	300	690	-	1 020	180	1 075	-	1 130	-	570
	F2	120	865	-	1 250	145	1 085	-	1 090	-	710
Good Black Soil (Kork Srok)	F0					160	2 035	240	1 380	-	1 675
	F1					170	2 020	200	1 340	-	1 720
	F2					135	1 950	210	1 320	-	1 635

Red Soil - average of 2 plots of 200 m² per fertilizers level
F0 = 0-0-0
F1 = basal 0-35-0 + top dressing 23 N on sesame and 60 K2O on Soybean
F2 = basal 0-170-30 in 2004, 0-35-30 in 2005-2007, 0-85-30 in 2008 + top dressing 23 N on Sesame + 60 K2O on Soybean
Black Soil - average of 3 plots of 200 m² per fertilizers level
F0 = 0-0-0
F1 = basal 0-35-0 + top dressing 23 N on sesame and 60 K2O on Soybean
F2 = basal 0-85-30 in 2006, 0-35-30 in 2007-2008 + top dressing 23 N on Sesame + 60 K2O on Soybean

Table VI. Yields (kg/ha of peeled, cut and sun dried tubers) on Red and Black soils of the reference cropping systems Cassava x PLOW

		2004	2005	2006	2007	2008
		Cassava	Cassava	Cassava	Cassava	Cassava
Good red soil (Sla)	F0	14 200	17 160	13 650		
	F1	14 750	15 400	13 250		
	F2	13 350	15 700	14 400		
Good Black Soil (Kork Srok)	F0			11 850	12 240	16 080
	F1			11 150	12 445	16 785
	F2			10 950	13 155	17 835

Red Soil - average of 2 plots of 200 m² per fertilizers level
F0 = 0-0-0
F1 = basal 0-35-0 + top dressing 69-0-60
F2 = basal 0-170-30 in 2004, 0-35-30 in 2005-2006 + top dressing 92-0-60

Black Soil - average of 3 plots of 200 m² per fertilizers level
F0 = 0-0-0
F1 = basal 0-35-0 + top dressing 69-0-60
F2 = basal 0-85-30 in 2006, 0-35-30 in 2007-2008 + top dressing 92-0-60

Creation of DMC

New cropping systems (crops successions and crops rotations x soil manangement based on no tillage) are firstly tested within "matrix" experimental design, where new DMC are compared to reference cropping systems, on 3 contrasted levels of fertilizers, on a multiannual basis. Between 2004 and 2008 (5 cropping seasons), PADAC has implemented 3 matrices in different small regions of Kampong Cham.

Preselected technologies (for agro-technical performances and fit with farmers production goals) in matrices are duplicated on demonstration plots, set up in the targeted areas for further pilot extension network development. These demonstration plots are rented to farmers, chosen for their "representativity" of biophysical conditions encountered across farmers' fields.

Systems based on short term biomass development for grain production

The first DMC's designed was based on a short term biomass production (or short term "Bio-pump" - BPsc), implemented during the first part of the rainy season, in replacement of the Sesame crops of the reference practises. Several species were successfully introduced and tested, chosen for their drought resistance, their ability to generate a big biomass in less than 60-70 days of growth and the easiness of seeds production:

- Sorghum (S. guineensis)
- Pearl Millet (Pennisetum glaucum)
- Finger Millet (Eleusine coracana)

These grass weeds species, implemented in line sowing (distance between lines of 0,4 m) with a no-till planter, showed out aerial biomass productions comprised between 6-7 t/ha (E. coracana) and 13-14 t/ha (Sorghum sp.) of dry matter on a F1 fertilizers level (with a top dressing application of 23N).

To introduce, legumes in the cover crops, prior to a Rice or Corn cycle, the association between E. coracana and Cajanus cajan (Pigeon pea), sown in alternate lines, was also tested; no clear improvement, compared to a pure Finger Millet cover, were noticed, likely due to a reduced production biomass.

In June, around 30 (Sorghum, Pearl Millet) to 25 days (E. coracana) prior to the desired sowing date for the main cycle, covers are rolled with a 1 m width Knife roller pulled by a power tiller and killed by a herbicides application (900 to 1080 g/ha of glyphosate mixed with 360 to 720 g/ha of 2,4 D amin).

Crops of Soybean, upland Rice and Corn were tested through this kind of systems with significant improvement on crops performances like show the comparison of the Tables V. and VII. for the degraded red soils.

Table VII. Yields (kg/ha, 14% humidity) on Red soils of the DMC BPsc Eleusine/ Soybean

		2004	2005	2006	2007
		Soy.	Soy.	Soy.	Soy.
Degraded Red	F0	540	1 070	745	1 060
Soil	F1	630	1 520	1 685	1 385
(Sahakreas)	F2	730	1 375	1 835	1 425

1 plots of 200 m² per fertilizers level
F0 = 0-0-0 - F1 = basal 0-35-0 + top dressing 23 N on BPsc Eleusine and 23-0-60 on Soybean
F2 = basal 0-170-30 in 2004, 0-35-30 in 2005-2007, + top dressing 23 N on BPsc Eleusine and 23-0-60 on Soybean

A first type of DMC was then created for short term crops, i.e. cycle below 135 days:

BPsc / Soybean
BPsc / upland Rice
BPsc / Corn

This type of system is easy to implement and comprehensible for farmers engaged in an initial phase of conversion from conventional to DMC based management. Moreover, under a usual constraint of heavy weeds pressure (one of the farmers' reason for conversion to DMC), a first control of dicotyledones weeds species (genus Borreria, Euphorbia, Celosia …) can be done by post application of 2,4 D amin post application (360 to 720 g a.i./ha) during the BPsc growth; this first control can be followed by a pre germination (or post initial) herbicide application in the main crops with active ingredient like alachlore for corn and soybean, oxadiazon for rice, imazetapyr for soybean … all products available on the Cambodian market.

But they present a major drawback: once harvest of the main crop done at the end of the rainy season, only crops residues remain on soil surface during the 5 months of the dry season; this situation represent an under-valorisation of the important water quantity stored in such soil profile (80 % clay) and of the scattered rainfalls which possibly occur in February and March.

Systems based on long term biomass development for grain production

To address this problem, technologies based on an implementation of a perennial cover crop species as catch crop in the main cycle were introduced and adapted in the meantime. Two fodder species were mainly used in this prospect, the legumes *Stylosanthes guianensis* var. CIAT 184 and the grass *Brachiaria ruziziensis*. These species, implemented prior to the harvest of the main crop, are able to survive and grow during the all 5 months dry season (long term "bio-pump", BPlc), exploiting the large soil water reserve, likely on more than 2 m depth, and catching for, an immediate production of supplementary biomass, all the scattered rains of February-April ("more crop per drop" !).

First associations were developed with Corn crops, then with upland Rice and Soybean as follow,

- Corn + Stylosanthes g.: Stylosanthes sown in the middle of the Corn inter-row (0,8 m) between 0 and 20 days after sowing (DAS) of the corn crops; possibility to apply alachlore or pendimethalin as pre-germination herbicide in case of high weeds pressure in first year and "light" cover (BPsc)
- Corn + Brachiaria r.: Brachiaria sown in the middle of the corn inter-row at 20 DAS of the corn; possibility to use atrazin (1000 g a.i./ha) in first year
- Upland Rice + Stylosanthes g.: Stylosanthes oversown in the middle of the Rice inter-row (0,4 m) at 40-50 DAS of the Rice; possibility to use oxadiazon (1000 ga.i./ha) in first year
- No association upland Rice + Brachiaria
- Soybean + Stylosanthes g.: Broadcast sowing (3 kg/ha) of Stylosanthes g. at the beginning of the Soybean maturation (appearance of the first yellow leaves)
- Soybean + Brachiaria r.: broadcast sowing (8-10 kg/ha) of Brachiaria r. at the beginning of the Soybean maturation; germination of the Brachiaria can be limited if the soil cover is still thick; in this case, the cover is strengthen, at the beginning of the next rainy season by an oversowing of a BPsc.

At the end of the dry season, these BPlc restart growing with the usually lost rainfalls of Februrary and March and then after developed a big biomass, up to 12-14 t/ha of Dry matter, in April-June. In June, 30 to 35 days prior to the desired sowing date for the main crop, the covers are rolled and killed by herbicides application (1080 g/ha glyphosate + 360 to 720 g/ha 2,4 D amin).

Stylosanthes g. is used as a cover crop for further Corn and upland rice cycles while Brachiaria r. is implemented for soybean cultivation. Then, these associations between crops and a BPlc allow to build various kind of permanent cropping rotations, like e.g.

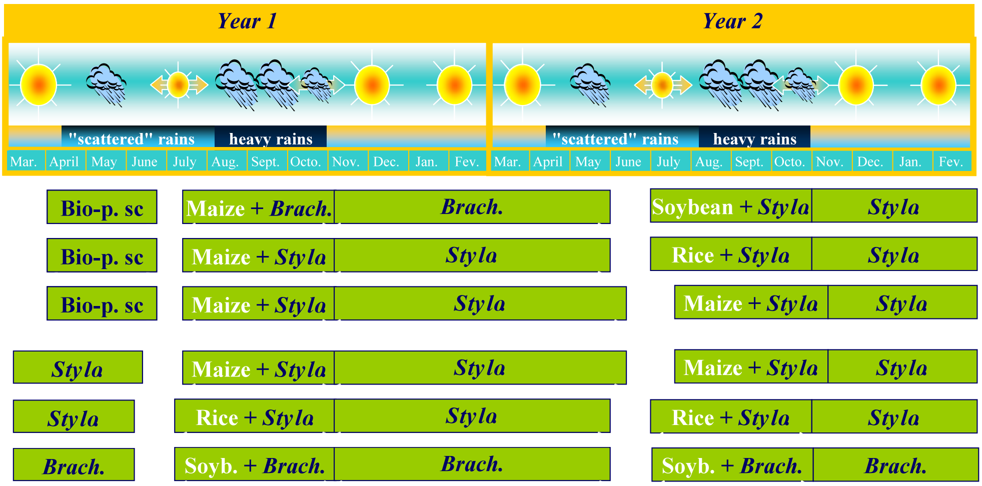
- BPsc / Corn + Stylo. // Stylo. / Corn + Stylo. … a "monocropping" of Corn on Stylosanthes g. cover
- BPsc / upland Rice + Stylo. // Stylo. / upland Rice + Stylo. … a "monocropping" of Rice on Stylosanthes g. cover
- BPsc / Corn + Stylo. // Stylo. / upland Rice + Stylo. … a biannual rotation of Corn and Rice on Stylosanthes g. cover
- BPsc / Corn + Brach. // Brach. / Soybean + Stylo. … a biannual rotation of Corn and Soybean on Stylosanthes g. and Brach. covers

… Etc …multiple possibilities of 2 or 3 years based rotations (figure n°2) and large flexibility for farmers for crops choices.

Table VIII. Yields (kg/ha, 14% humidity) on Red soils of various DMC rotation based on BPlc
2 demonstration sites with elementary plots of 3 000 to 6 000 m² per fertilizers level
F0 = 0-0-0 + top dressing 23 N on the main crops (Corn, Soyean or upland Rice)
F1 = basal 0-35-0 + top dressing 23 N on BPsc Eleusine and 23-0-60 on Soybean, 69-0-30 on Corn and 46-0-30 on Rice

	2006		2007		2008	
F1	BPsc Eleusine/ Soybean	2 035	BPsc Eleusine/ Corn + Brach.	5 065	Brach./ Soybean + Stylo.	2 195
F1	BPsc Eleusine/ Corn + Brach.	4 380	Brach./ Soybean + Stylo.	2 610	Stylo./ Corn + Brach.	6 600
F0	Brach./ Soybean + Brach.	1 015	Brach. + BPsc Eleusine/ Corn + Brach	1 835	Brach./ Soybean + Stylo.	1 880
F1		1 615		3 320		2 145
F0	BPsc Eleusine/ Corn + Brach.	3 475	Brach./ Soybean + Stylo	1 235	Stylo./ Corn + Brach.	5 790
F1		5 165		1 535		6 080
F0	BPsc Eleusine + Cajanus/ Rice	2 805	BPsc Eleusine + Cajanus/ Corn + Stylo.	3 725	Stylo./ Rice + Stylo.	3 235
F1		2 330		4 355		4 690
F0	BPsc Eleusine/ Corn + Stylo.	3 715	Stylo./ Rice + Stylo.	2 735	Stylo./ Corn + Stylo.	6 220
F1		5 360		3 955		5 540

figure n°2. Examples of DMC bi-annual rotations based on BPlc



Despite still some yield limitations for Soybean (likely primarily due to genetic potential of the local variety, inferior of 2,8 t/ha) and upland Rice (due to high insects pressure on roots including the genus Dysmicoccus and/or Rhopalosiphum), the results presented in the Table VIII. show out pronounced improvement within one rotation cycle, with limited fertilizers applications.

Systems based on long term biomass development and secondary crops for grain production

New design of systems are currently tested and still under a multi-annual assessment proceed; they are based on the introduction of a secondary crops, sown late in the rainy season, between 45 and 30 days before the "expected" date of the last significant rainfalls. This "expected date" being quite unpredictable, the introduced secondary crop is implemented at a minimum cost in order to limit economic risk. A requested good draught resistance drives the choice on Sorghum (S. bicolour) and pearl Millet (P. glaucum), sown in association with the BPlc, Stylosanthes g. and Brachiaria r.

These secondary crops are mainly tested in succession of a Soybean, with 2 technical options:

- as a succession of a Soybean short cycle variety (90 to 100 days), harvested en of September, early October;
- as a catch crop, broadcasted at the appearance of the first yellow leaves of a Soybean medium cycle variety (110-125 days), about one month prior to the harvest (end of October-early November)

The first orientation presents several drawbacks: (1) reduced soybean potential with a short cycle, (2) risk to have a grain maturation and harvest occurring during a large rains periods (with almost no post harvest drying facilities) and (3) higher cost induced by the line sowing

This approach allows the re-introduction of a secondary crop, like in the farmers' reference, but in a more secured way, due to a connection to the soil water reserve and not dependant on the randomized rainfalls of April-June.

DMC and Cassava production

Cassava based DMCs with BPsc Eleusine were first tested within matrices, on both red and black soils. But the delayed planting, after the biomass production, late June instead of mid April in farmers' reference management, induced pronounced yield decreases (up to 40 %) leading to a rapid abandon of this option.

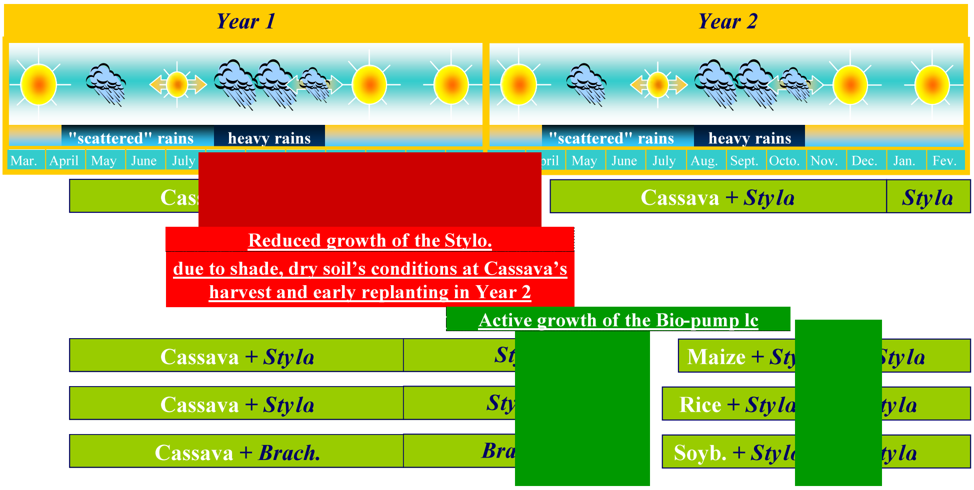
In the meantime, association between Cassava and BPlc (*Stylosanthes guianensis* and *Brachiaria ruziziensis*) were assessed in matrices and demonstration plots with ambivalent results; association between Cassava and Brachiaria r. is possible with a delayed implementation of the Brachiaria in the middle of the Cassava inter-row (0,8 to 1,0 m) at the appearance of the first leaflets, around 2 weeks after planting ; but when implemented on degraded soil with a weak growth of the Cassava, the Brachiaria strongly competes the crop and limits yields. Such an association is thus difficult to recommend to farmers, although some of them are very interested by the associated fodder production as a cut and carry source for cattle feeding.

Stylosanthes, sown at planting -if no strong weeds pressure- or, a contrario, around 20 days later after a first weeding, with a slower initial growth, is more easily controlled by the progressive inter-row shading with Cassava development.

This efficient association opens ways to the construction of Cassava based DMCs necessarily relying on, at least bi-annual- crops' rotations (figure n°3); indeed Cassava monocropping with late harvest in the middle of the dry season and early planting doesn't allow a significant growth of the Stylosanthes between two Cassava cycles.

As presented in the figure n°3., Cassava associated to Stylosanthes g. BPlc can be managed in bi-annual rotations with Corn and upland Rice; in such scheme, the BPlc can develop big biomass at least one year for 2, prior to and after the short cycle crops of the rotation. Cassava associated to Brachiaria r. in rotation with Soybean + Stylosanthes g. are still under assessment.

figure n°3. Examples of Cassava based DMCs



This initial phase of controlled experimentations leads to the creation of diversified and flexible cropping systems able to address the mains local and regional market's demands, relying mainly on animal feed and a soaring bio-fuel sectors.

The most promising systems (easiness to implement, crops performance, resilience with climat "hazards" and buffer of market variations through diversification …) are tested on larger demonstration plots network, used to assess the variability of the technico-economic performances and to discuss with farmers groups wishing to start adoption of DMC within a pilot extension network.

In term of cropping systems improvements, complementary works are needed:

● the matic adjustments on the already proposed DMC, principally based on BPlc with Brachiaria r., Stylosanthes g. or an association of the 2 sp., like
- Soybean varieties selection in order to reach productivity above 2,8 – 3,0 t/ha
- upland Rice varieties selection addressing quality and soil's insects pressure
- fertilizers levels and interest of complementary applications of Sulpfur and micro-nutrients
- optimization, between biomass recycling/ soil fertility increase and the generation of complementary incomes through the exploitation of the BPlc as forage for cattle

● new systems' design in order to balance some weak points of this first batch of DMC,
- herbicides and pesticides use reduction (once inherited weeds' pressure from plow based management has been reduced), firstly the application done to control the cover crops prior to sow the main crops
- little specific diversity in the crops rotation, with only 3 to 4 species in 2 years.

Further systemic orientations in DMC development

Further systemic orientations in DMC creation will be done through two complementary orientations in order to pursue a double goal of improved productivity and reduced ecological impact of the designed cropping systems.

Increased species diversity in the rotations and cover crops functionalities

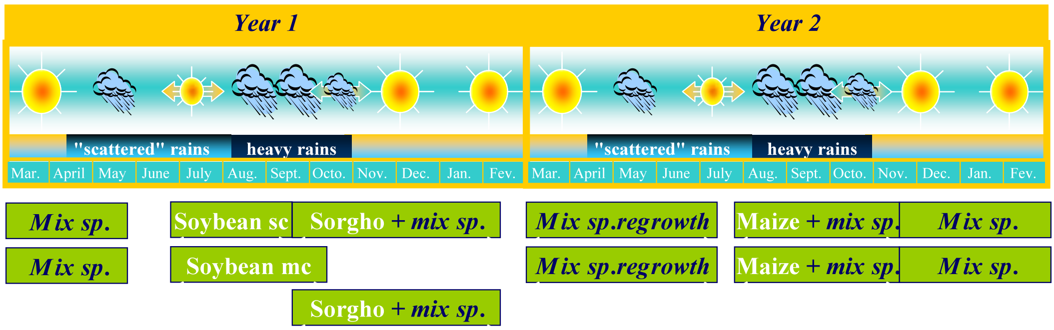
DMC based on BPlc generates high (up to more than 20 t/ha of aerial dry matter with a corn + *Stylosanthes guianensis* association) and continuous (with roots' exudation) organic matter inputs on soil surface and in soil profile. This almost continuous injection of large quantity of organic carbon substratum triggers an important soil's activity, even during the dry season, thanks to the connection to water reserves by the cover crops.

It can be reasonably assumed that an increased number of plant species in the rotation (crops and cover crops), will induce a higher diversity of associated organisms, for both fauna and microflora, progressively leading to real and more resilient agro-ecosystems.

In this view, mix of annual species from various families will be associated to the main crops:

- Poaceae, genus Sorghum, Pennisetum, Eleusine …
- Leguminosae, genus Centrosema, Crotalaria, …
- Cruciferae, genus Raphanus
- Labiaea, genus Ocimum, Hiptis
- Polygonaceae, genus Fagopyrum,
- Amaranthaceae, genus Amaranthus
- …

figure n°4. Example of future DMC design based on cover made of a mixture of various annual species



These species are chosen in order to complete income (at least one species of the mixture must be harvested with a commercial purpose) and introduce, beside the biomass inputs, functionalities like allelopathy for weeds control, repulsive (push) – attractive (pull) effect on soil pest insects, nitrogen fixing …

Some of these species may have the possibility to restart at the beginning of the following rainy season (like Sorghum) or will germinate from the seeds fallen on soil surface leading to the spontaneous reproduction of BPsc cover type.

Progressive reduction of agrochemicals … toward strict "organic" management of DMC

Preliminary results have shown the capacity of DMC to reach high crops yields with limited mineral fertilizers levels (e.g. more than 6 t/ha of corn with 23 N application in Stylosanthes based systems). Obviously, DMC with high Carbon inputs open the ways for productive and sustainable "organic" farming, based on high organic matter recycled in plant-soil system.

DMC leads also to the creation of real agro-ecosystems where balance between pest and predators will be more easily maintained when compared with plow based, with bare soil, cropping systems.

Back to menu

The first step to be achieved in the development of "organic" (or at least agro-chemicals free) DMC will be the suppression of herbicides use, especially the application of glyphosate and 2,4 D amin mixture used to kill the cover crops prior to the main crops implementation. Two directions are or will be tested and set up in the coming cropping seasons within PADAC:

- control by a combination of mechanical (roller knife) management and salted solutions applications (NaCl, KCl)
- strict mechanical management (roller chopping, mowing …)

These kinds of managements might be easier to achieve with cover made of an annual crops' mixture than with perennial species like Stylosanthes g. and Brachiaria r.

Conclusion

The creation of a DMC based alternatives to reference farmers cropping systems based on soil tillage has been initially "grafted" on the local practises, firstly developed cropping systems just proposing to replace the hazardous Sesame crops by a biomass production to generate the first cover crop.

The second "generation" of DMC is based on association with perennial cover-fodder crops and offers, compared to the first one, strongly strengthened biomass inputs in the soil-plant system, leading to a rapid recovering of soil fertility parameters (chemical, physical and biological).

The next step will work simultaneously on an introduction of more "information" in the systems toward an increased plants species diversity in the rotation combined with a progressive reduction of the agro-chemical via the replacement of the herbicide and the reduction of mineral and/or organic fertilizers application to a level calculated to balance exportations by grains and grazings.

This evolution fits also with the way to progressively extend DMC, which represent a deep systemic change, with farmers groups, as represented on the figure n°5.

figure n° 5. Parallel between DMC creation and DMC adoption sequences