



Centre
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**MANUAL FOR
ESTABLISHMENT AND MEASUREMENT
OF
PERMANENT SAMPLE PLOTS
IN
PLANTATIONS**

CIRAD-Forêt - MIDAS - Burapha

Lao ADB Plantation Forestry Project - Loan No, 1295 (SF)

17 September 1996

Ref : Plantation Management No. 27

Prepared by Tom Brummer

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TABLE OF CONTENTS

	Page
A. Requirements for Permanent Sample Plot (PSP) Field Work	2
B. PSP Type	3
C. Establishing a new PSP	4
D. Maintenance Before Measuring a PSP	9
E. PSP Measurement and Remeasurement Procedure	10
F. Notes on PSP Technique	13
H. Table of Plot Half Diagonal Distance	14
I. Table of Heights Derived from Top and GBH Angles	16
J. PSP Measurement Form	18

A. REQUIREMENTS FOR PERMANENT SAMPLE PLOT (PSP) FIELD WORK

1. Plantation map
2. Clinometer
3. Compass
4. Measure tape for tree girth (normal taylor's tape in cm and mm)
5. Stick 1.3 m long (GBH stick)
6. 20 m measure tape
7. Manual for Measurement of Permanent Sample Plots
8. Table of Plot Half Diagonal Distance
9. Tree Height Table
10. PSP Measurement Forms
11. Slasher (pha)
12. Hammer for pegs
13. Tree number marker (water proof marker, black)
14. Pegs (6 per plot)
15. Clipboard
16. Pencils
17. Red paint & brush
18. Calculator
19. Photo copy of PSP Measurement Forms from last measurement
20. Bag to carry the smaller items above

B. PSP TYPE

Permanent Sample Plots (PSP) are used to monitor the growth and development of a stand over the whole of its life. PSPs will provide information on growth rate, volume, tree size, product type and can be used to construct a predictive growth model for other similar younger plantations and also to provide data for various types of economic assessment and even to derive a value for a plantation.

The type of plot used in this manual is called a "Diamond Plot" (see Fig. 1). It is marked with 5 pegs;

- A : centre peg
- B : corner peg - up hill
- C : corner peg - down hill
- D : corner peg - left
- E : Corner peg - right

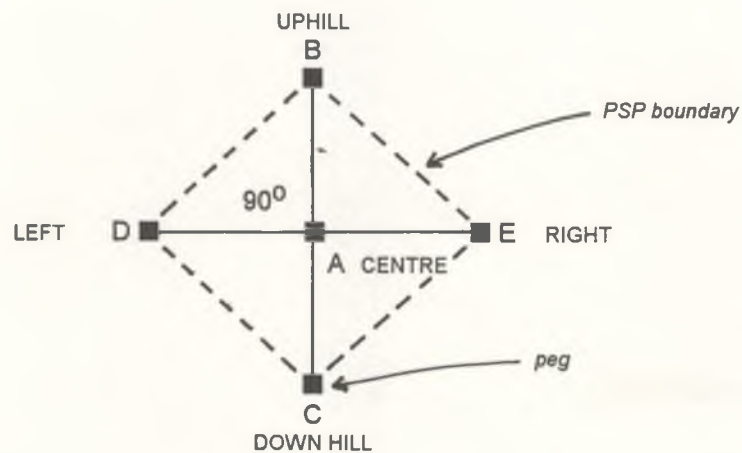


Fig. 1

- Note :
- i) Lines BC and DE are at 90° .
 - ii) On flat ground only, $BC = DE$.
 - iii) On sloping ground the **distance along the ground** $BC \neq DE$, but the **horizontal distance** of $BC = DE$ (see Fig. 2).

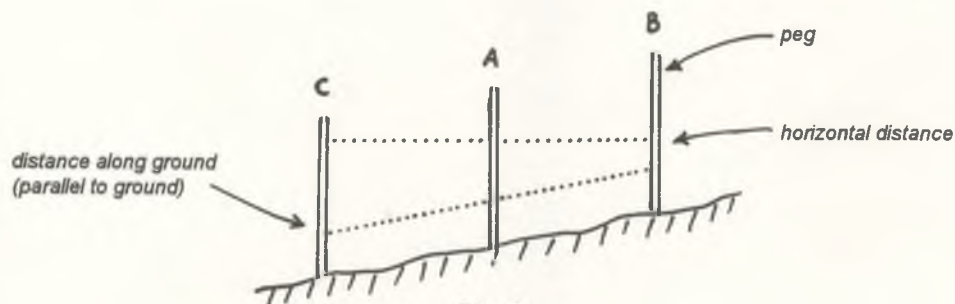


Fig. 2

C. ESTABLISHING A NEW PSP

The PSP location is planned on a plantation map in the office before going to the field and this is done according to the sampling plan. In the field the method for establishing a new PSP is as follows;

1. Go to the plantation and find the stand in which the PSP will be established.
2. Hammer into the ground a peg at the roadside at the point where you will leave the road and go into the stand. This is to make the PSP easy to find for future measurements.
3. According to your instructions on the map measure the distance and compass direction (bearing) to the PSP. When you arrive at the PSP hammer into the ground the centre peg (A).
4. Measure in degrees the slope from centre peg directly uphill and then directly downhill with Clinometer. Measure from your eye to your assistant, be sure to aim at a point on your assistant which is the same height as your own eye, (check where this is while standing face to face). For these slope measurements your assistant should be approximately 10 m away from you.
5. Add the uphill and downhill slopes, disregard the positive (uphill) and negative (downhill) slopes. Divide the total by 2 to get average slope for the PSP and write it on the back of PSP Measurement Form in the Plot Diagram.

e.g. uphill + 5°
 downhill - 1°
 6° (disregard the positive or negative signs)

then divide by 2

= 3° average slope

6. See the **Table of Plot Half Diagonal Distance** and use PSP size as follows;

☛ use 200 m² PSP for 2x3 m planting (1,666 trees per ha)

☛ use 200 m² PSP for 3x3 m planting (1,111 trees per ha)

☛ use 200 m² PSP for 2x5 m planting (1,000 trees per ha)

☛ use 400 m² PSP for 4x3 m planting (830 trees per ha)

then select the half diagonal distance for plot size and average slope.

7. Measure the half diagonal distance indicated in the **Table of Plot Half Diagonal Distance** directly uphill from the centre peg (A) to the uphill peg (B) position and hammer into the ground the uphill peg. Use the same distance to measure directly downhill from the centre peg to the down hill peg (C) position and hammer into the ground the downhill peg. Measurements must be precise. The measuring tape must be firmly pulled and it must be parallel to the ground slope (see Fig. 3).

when measuring peg positions
tape must be held parallel
to the ground, not horizontal

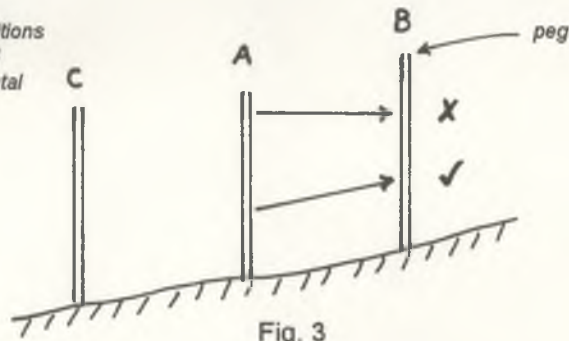


Fig. 3

8. Locate and hammer into the ground the left (D) and right (E) pegs in a similar manner by measuring the average slope. Locate the peg positions using the half diagonal distance for the plot size and average slope from the table.

Use the compass to make sure that line BC is 90° from line DE. Write the plot measurements, average slope and compass bearings on back of PSP Measurement Form in the "Plot Diagram".

Make sure that lines BC and DE are straight with pegs BAC and DAE forming a straight line (see Fig. 4).

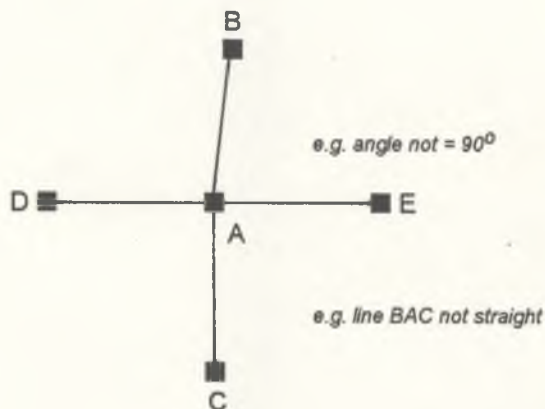
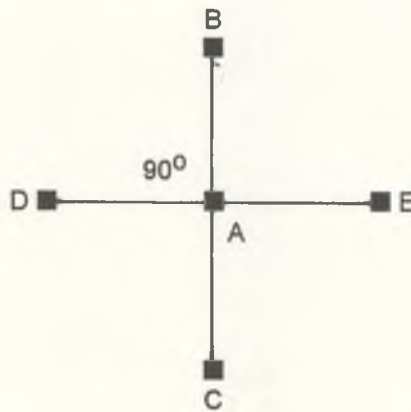


Fig. 4

9. Measure the distance (to 0.1 m) from centre peg (A) to the closest live tree. Also measure the compass bearing from centre peg to that same tree (see Fig. 5). This tree is called a "Witness Tree" (WT). On the WT write WT at about your head height and facing to the centre peg. Record the distance and compass bearing to the WT on the back of the PSP Measurement Form.

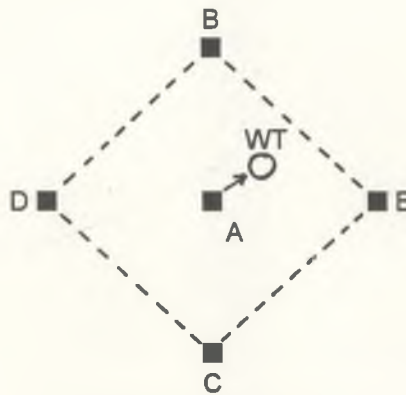


Fig. 5

10. Measure with compass the bearing from the centre peg (A) to the uphill peg (B), downhill peg (C), left peg (D) and right peg (E) and record onto the Plot Diagram at the back of the PSP Measurement Form (see Fig. 6).

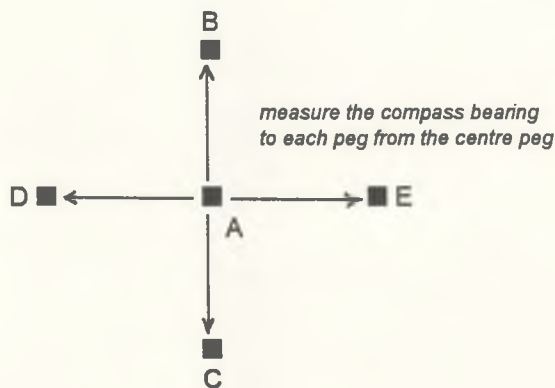


Fig. 6

11. Use slasher (pha) to clear any vegetation which is blocking vision along the plot boundaries.
12. From the uphill peg (B) look to the left peg (D) and direct your assistant to paint a 2 cm wide ring, horizontally around the tree stem, exactly 1.3 m above the ground on each tree that has its centre inside the plot boundary. Use the GBH stick to measure the correct height of the GBH ring. Stand the GBH stick on the ground on the uphill side of the tree if there is any ground slope. (See Fig. 7). These painted rings are called "GBH rings".

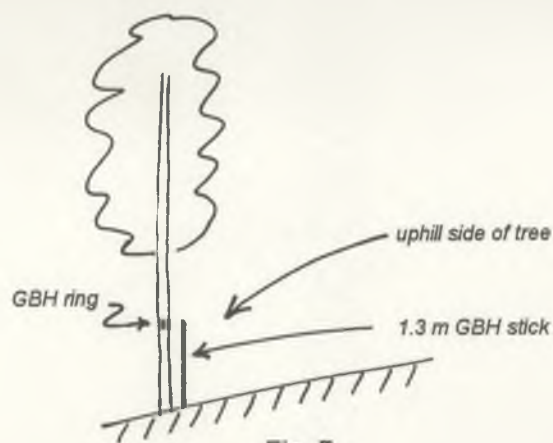


Fig. 7

From the uphill peg (B) look to the right peg (E) and paint the GBH rings on the trees near the boundary which are inside the plot.

If the centre of a tree is exactly on the PSP boundary line it is called a "marginal tree". Any marginal trees on the uphill boundaries DB and BE are "inside" the PSP so paint a GBH ring on them.

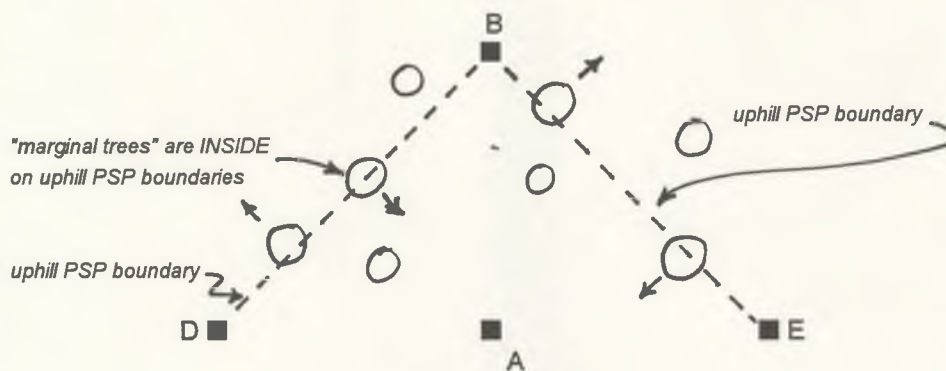


Fig. 8

13. From the downhill peg (C) look to the left peg (D) and the right peg (E) and mark the GBH ring on all trees near the boundary which are inside the PSP.

Any marginal trees on these downhill boundaries DC and CE are "outside" the PSP and are therefore ignored.

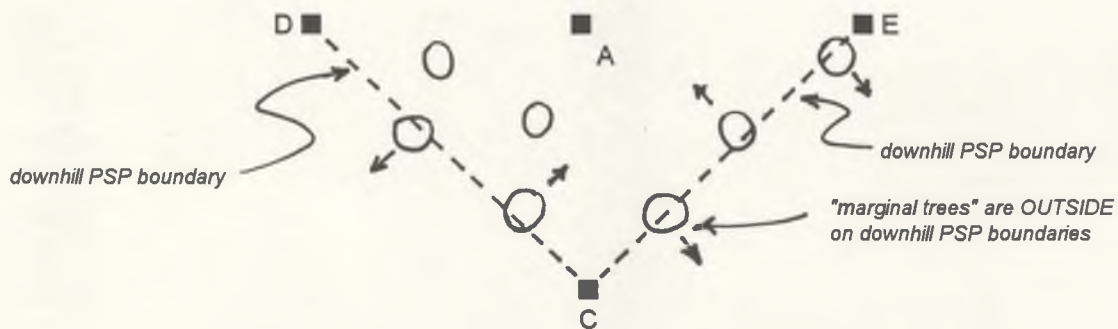


Fig. 9

14. Paint GBH rings on all other trees that are inside the PSP.
15. Clearly write the number on each tree that is inside the PSP just above the GBH ring. The tree number sequence will run back and forth along the planting rows in an S pattern. To make it easy to find a tree number make sure all numbers and the letters WT face towards one of the corner pegs (See Fig. 10).



Fig. 10

D. MAINTENANCE BEFORE REMEASURING A PSP

PSPs should be established in the second dry season after planting when the trees will be about 1 year and 6 months old. Stands that have not grown to more than 2 m in height during this time can not be measured. A PSP should be remeasured every year in the same month that it was established. When a PSP is to be remeasured the following maintenance is required just before tree measurement is started;

1. Take to the field a photo copy of the PSP Measurement Form made the previous year. Do not take the original out to the field, if it is lost or damaged the PSP could lose it's data and therefore it's usefulness for data collection and a number of years of work can be lost.
2. Check that all pegs are in place, straighten them and make sure they are firm in the ground. Replace any that are rotted or broken.
3. Cut down any vegetation that blocks your view of GBH rings.
4. Measure all distances and compass bearings from centre peg (A) to each of the other pegs (B,C,D,E) and to the WT. Check that they are the same as last year's measurement from the plot layout diagram. If they are not then you may have the PSP Measurement Form of another plot, check carefully the PSP Number.
5. If some pegs are missing their position can be relocated using the distances and compass bearing from the "Plot Diagram". Be sure that you do this correctly or the plot will be of no use for data collection, if you are not sure then inform the PCU and ask them to assist.
6. Remove any loose bark by hand, repaint the GBH rings, rewrite the tree numbers and WT. Do this every year even if the rings and numbers are still clear because they can not last one more year till the next measurement.

E. PSP MEASUREMENT AND REMEASUREMENT PROCEDURE

1. On the front of the PSP Measurement Form carefully fill out the information about the PSP;

- Date
- Plantation name & District
- Stand No.
- PSP No.
- Species and Planting year
- Times Measured, e.g. first measurement = 1, second measurement =2, etc.
- Measured by

2. On the back of the PSP Measurement Form carefully fill out the information about the PSP;

- Check that the Plot Diagram is filled in.
- Write in the "note on how to find the plot".

3. Measure GBH of all live trees in the PSP. Measure the GBH to nearest 0.1 cm. Write it on the form in clear figures next to it's correct Tree No.

4. For each tree that you measure GBH also choose the "Tree Code" which best describes the tree (see Fig. 11). Write a clear capital letter on the PSP Measurement Form. Choose a Tree Code from the following list;

- N** - NORMAL : single stem with balanced branching, straight or only slight curve so tree can be used for one or more poles.
- K** - KINKED : one or more kinks so tree can not be used for a pole.
- F** - FORK : tree is divided into two or more stems.
- B** - BRANCH : tree has one stem but one or more major branches much larger than the others.
- D** - DEAD : tree is now dead, dead trees are not measured.

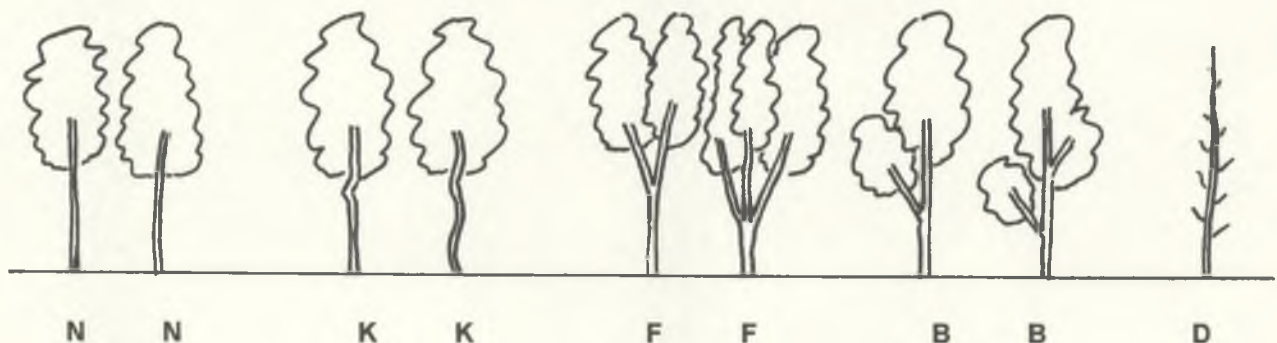


Fig. 11

5. Each time the PSP is measured 3 Height Trees will be chosen to be measured for height in the following way. After all GBHs have been measured and written onto the PSP Measurement Form calculate the average GBH of the PSP.

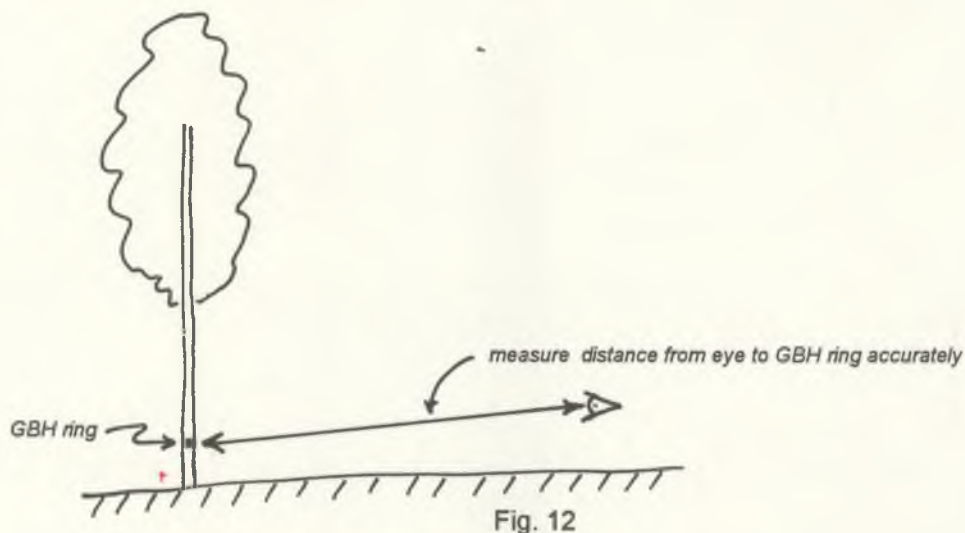
From the PSP Measurement Form find the Tree No. which has the GBH closest to the average GBH of the PSP. Then find the Tree No. of the next larger GBH and the next smaller GBH.

These three tree Nos. can change each year of measurement so choosing of the three Height Trees must be done each time the PSP is measured.

Check by eye that the 3 Height Trees are of normal form (not broken, forked, deformed, pushed over by the wind etc.) and representative of the stand. If not, then replace it with the next closest to average GBH, next larger GBH or next smaller GBH tree.

6. Write the 3 Height Tree No. and their GBH in the "Height Tree Data" section of the PSP Measurement Form.
7. Use Clinometer to measure Height Trees. For each tree choose a position where the tree top and GBH ring can be clearly seen.

By eye estimate the stand height to the nearest 5 m, 10 m, 15 m, or 20 m. Find that mark on the 20 m tape and accurately measure that distance from your eye to the GBH ring on the tree (see Fig. 12)



With the Clinometer measure the angle (in degrees) to the top of the tree and then to the GBH ring. Repeat the measurements again to be sure they are correct and write them carefully on the PSP Measurement Form beside the Tree No. (see Fig. 13).

The top angle must be positive (looking up) and within the range $+30^{\circ}$ to $+53^{\circ}$. The GBH angle can be negative (looking down) or positive (looking up) within the range -30° to $+15^{\circ}$.

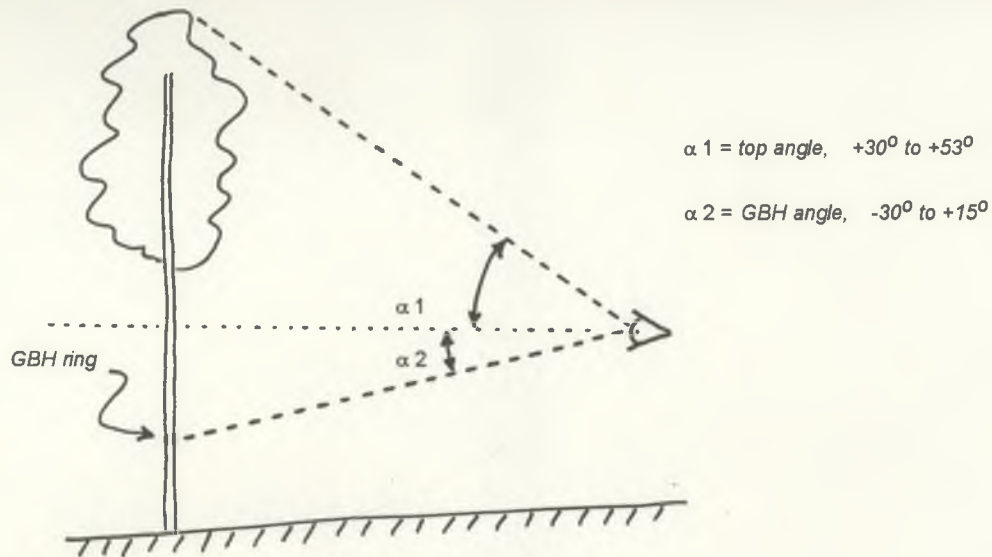


Fig. 13

8. Calculate the tree height using the **"Table of Heights Derived from Top and GBH Angles"** and write in the "Table Height" column of the "Height Tree Data" section of the PSP Measurement Form. This table is in section I of this manual.

The height from the **"Table of Heights Derived from Top and GBH Angles"** is called the "Table Height" on the PSP Measurement Form. Table Height is the tree height from GBH ring to the tree top, so it is necessary to add the GBH height of 1.3 m, from ground to GBH Ring, to get the true Tree Height. On the PSP Measurement Form there are columns for you to do this calculation.

The "Tree Height" is always written in metres to the nearest 0.1 m e.g. 15.0, 12.7

9. Before leaving the plot make sure every part of the PSP Measurement Form has been filled in correctly. Check carefully all your calculations that they are correct, especially the heights. Compare this season's measurements for each GBH to the last measurement and see that they are consistent; e.g. a tree may have a smaller GBH this year than last year, e.g. a tree may have grown only 0.2 cm of GBH since the last measurement but the others have grown about 8 cm. If you find such an anomaly you must remeasure that tree to be sure of the new data before you leave the PSP. This is much easier and cheaper than coming back later to check the anomaly.

F. NOTES ON PSP MEASUREMENT TECHNIQUE

1. If a tree divides into 2 or more stems below the GBH ring then each stem is measured as a separate tree with it's own tree number. This refers to true stem division (Tree Code F) and not a large branch below GBH (Tree Code B). Such a tree with a divided stem is not normal or representative of the stand and should not be used for height measurement.
2. A tree with a large branch (Tree Code B) but otherwise normal can be used as a Height Tree.
3. If a tree was alive and measured last year but is found to be dead this year, do not measure it for GBH or as a Height Tree. Only write D in it's "Tree Code". Do not change the numbers of the other trees.
4. Once trees in the PSP have been numbered at the first measurement they must keep that same number every year and not change.
5. If a tree has been broken above GBH it may be measured for GBH but can not be used as a Height Tree. But you must make a note of this in the "Comments" section of the PSP Measurement Form, write the estimated height of the break. If a tree has been broken below GBH it is treated as a dead tree, note it in the comments also.
6. If a tree has been pushed over by wind or animals since the last measurement GBH is measured at it's old GBH ring. But this tree can not be used as a Height Tree. It must be noted in the "Comments" section of the PSP Measurement Form.
7. When writing notes about a tree in the "Comments" section of the PSP Measurement Form be sure to also write the Tree No. the note is about.
8. It is important to write a note in the "Comments" section about anything unusual in the PSP which could have an effect on tree growth; e.g. some disease on the trees, e.g. flooding in the stand since the last measurement, e.g. damage by buffalo, or fire etc.
9. When measuring the top and GBH angles hold the Clinometer to your eye with one hand and hold the tape at the chosen distance in the other hand against your cheek. During the angle measurement pull the tape tight as possible. Your assistant will hold the zero mark of the tape to the GBH ring.
10. To get data on tree diameter in the PSP it is recommended to measure tree girth (circumference). This is done at Breast Height which is 1.3 m above the ground on the uphill side of the tree. This measurement is called Girth at Breast Height (GBH).

It is difficult and very expensive to get special diameter tapes. Therefore use a good quality "taylor's measuring tape" to measure GBH and later in the office convert GBH to Diameter at Breast Height (DBH). To do this divide GBH by π .

GBH is measured in cm to the nearest 0.1 cm. Diameter at Breast Height (DBH) is written in cm to the nearest 0.1 cm also e.g. 5.2, 7.0
11. When measuring heights using the "Suunto PM-5" clinometer be sure that you; read the left scale only, and note if the angle is positive (looking up) or negative (looking down).

ຕາຕະລາງ ການຊອກຫາ ໄລຍະຫ່າງ ຂອງເສັ້ນຜ່ານນູນ ຂອງສ່ວນທີ່ດຽວ

TABLE OF PILOT HALF DIAGONAL DISTANCE

ຄ່າສະເລ່ຍ ຂອງຄວາມຊັນ Ave. Slope	1/2 ຄວາມຍາວ ຂອງເສັ້ນຜ່ານນູນ (m)		
	100 m ²	200 m ²	400 m ²
		2x3 m , 3x3 m, 2x5 m	4x3 m
0°	7.07	10.00	14.14
1°	7.07	10.00	14.14
2°	7.07	10.00	14.15
3°	7.08	10.01	14.15
4°	7.08	10.01	14.16
5°	7.08	10.02	14.17
6°	7.09	10.03	14.18
7°	7.10	10.04	14.20
8°	7.11	10.05	14.21
9°	7.12	10.06	14.23
10°	7.13	10.08	14.25
11°	7.14	10.09	14.27
12°	7.15	10.11	14.30
13°	7.16	10.13	14.33
14°	7.18	10.15	14.36
15°	7.19	10.17	14.39
16°	7.21	10.20	14.42
17°	7.23	10.23	14.46
18°	7.25	10.25	14.50
19°	7.27	10.28	14.54
20°	7.29	10.32	14.59
21°	7.32	10.35	14.64
22°	7.34	10.39	14.69

ຄາລະເລຍ ຂອງຄວາມຊັນ Ave. Slope	1/2 ຄວາມບາວ ຂອງເສັ້ນຜ່ານນ (ມ)		
	100 m ²	200 m ²	400 m ²
		2x3 m, 3x3 m, 2x5 m	4x3 m
23°	7.37	10.42	14.74
24°	7.40	10.46	14.80
25°	7.43	10.50	14.86
26°	7.46	10.55	14.92
27°	7.49	10.59	14.98
28°	7.53	10.64	15.05
29°	7.56	10.69	15.12
30°	7.60	10.75	15.20
31°	7.64	10.80	15.28
32°	7.68	10.86	15.36
33°	7.72	10.92	15.44
34°	7.77	10.98	15.53
35°	7.81	11.05	15.63
36°	7.86	11.12	15.72
37°	7.91	11.19	15.82
38°	7.97	11.27	15.93
39°	8.02	11.34	16.04
40°	8.08	11.43	16.16
41°	8.14	11.51	16.28
42°	8.20	11.60	16.41
43°	8.27	11.69	16.54
44°	8.34	11.79	16.67
45°	8.41	11.89	16.82

ໜ້າ 2 ຂອງ 2

ຕາຕະລາງລວງສູງ ຊອກໄດ້ຈາກ ມູນທາງຕັ້ງ ຈາກປາຍໄມ້ ແລະ ບ່ອນ DBH

TABLE OF HEIGHTS DERIVED FROM TOP ANGLE AND DBH ANGLE .

(For a measured distance of M multiply M/10 by Table Height)

e.g. : DBH angle = -25 deg., top angle = 38 deg., m = 22.4 Tree height from DBH to top = $22.4 / 10 \times 11.3 = 25.3$ m.

		TOP ANGLE (degrees)														(ມູນໄດ້ຈາກ ຕາຕະລາງສູງ)													
		30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53				
DBH ANGLE DEG ມູນຈາກປາຍໄມ້	-30	10.0	10.2	40.4	10.6	10.8	11.0	11.3	11.5	11.8	12.0	12.3	12.5	12.8	13.1	13.4	13.7	14.0	14.3	14.6	15.0	15.3	15.7	16.1	16.5				
	-29	9.9	10.0	10.3	10.5	10.7	11.0	11.2	11.4	11.7	11.9	12.2	12.5	12.7	13.0	13.3	13.6	13.9	14.2	14.6	14.9	15.3	15.6	16.0	16.5				
	-28	9.8	10.0	10.2	10.4	10.7	10.9	11.2	11.3	11.6	11.8	12.1	12.4	12.6	12.9	13.2	13.5	13.8	14.1	14.5	14.9	15.2	15.6	16.0	16.4				
	-27	9.7	9.9	10.1	10.3	10.5	10.8	11.0	11.3	11.5	11.8	12.0	12.3	12.6	12.8	13.1	13.4	13.8	14.1	14.4	14.8	15.2	15.5	15.9	16.4				
	-26	9.6	9.8	10.0	10.2	10.4	10.7	10.9	11.2	11.4	11.7	11.9	12.2	12.5	12.8	13.1	13.4	13.7	14.0	14.4	14.7	15.1	15.5	15.9	16.3				
	-25	9.5	9.7	9.9	10.1	10.3	10.6	10.8	11.1	11.3	11.6	11.8	12.1	12.4	12.7	13.0	13.3	13.6	13.9	14.3	14.7	15.0	15.4	15.8	16.3				
	-24	9.3	9.6	9.8	10.0	10.2	10.5	10.7	11.0	11.2	11.5	11.7	12.0	12.3	12.6	12.9	13.2	13.5	13.9	14.2	14.6	15.0	15.3	15.8	16.2				
	-23	9.2	9.4	9.7	9.9	10.1	10.4	10.6	10.8	11.1	11.4	11.6	11.9	12.2	12.5	12.8	13.1	13.4	13.8	14.1	14.5	14.9	15.0	15.7	16.1				
	-22	9.1	9.3	9.5	9.8	10.0	10.2	10.5	10.7	11.0	11.3	11.5	11.8	12.1	12.4	12.7	13.0	13.3	13.7	14.0	14.4	14.8	15.2	15.6	16.1				
	-21	9.0	9.2	9.4	9.6	9.9	10.1	10.4	10.6	10.9	11.1	11.4	11.7	12.0	12.3	12.6	12.9	13.3	13.6	14.0	14.3	14.7	15.1	15.5	16.0				
	-20	8.9	9.1	9.3	9.5	9.8	10.0	10.2	10.5	10.8	11.0	11.3	11.6	11.9	12.2	12.5	12.8	13.2	13.5	13.9	14.2	14.6	15.0	15.4	15.9				
	-19	8.7	8.9	9.2	9.4	9.6	9.9	10.1	10.4	10.6	10.9	11.2	11.5	11.8	12.1	12.4	12.7	13.0	13.4	13.8	14.1	14.5	14.9	15.4	15.8				
	-18	8.6	8.8	9.0	9.3	9.5	9.7	10.0	10.3	10.5	10.8	11.0	11.4	11.7	12.0	12.3	12.6	12.9	13.3	13.7	14.0	14.4	14.8	15.3	15.7				
	-17	8.4	8.7	8.9	9.1	9.4	9.6	9.9	10.1	10.4	10.7	10.9	11.2	11.5	11.8	12.2	12.5	12.8	13.2	13.5	13.9	14.3	14.7	15.2	15.6				
	-16	8.3	8.5	8.8	9.0	9.2	9.5	9.7	10.0	10.3	10.5	10.8	11.1	11.4	11.7	12.0	12.4	12.7	13.1	13.4	13.8	14.2	14.6	15.1	15.5				
	-15	8.2	8.4	8.6	8.9	9.1	9.4	9.6	9.9	10.1	10.4	10.7	11.0	11.3	11.6	11.9	12.2	12.6	12.9	13.3	13.7	14.1	14.5	15.0	15.4				
	-14	8.0	8.2	8.5	8.7	9.0	9.2	9.5	9.7	10.0	10.3	10.6	10.9	11.2	11.5	11.8	12.1	12.5	12.8	13.2	13.6	14.0	14.4	14.9	15.3				
-13	7.9	8.1	8.3	8.6	8.8	9.1	9.3	9.6	9.9	10.1	10.4	10.7	11.0	11.3	11.7	12.0	12.3	12.7	13.1	13.5	13.9	14.3	14.7	15.2					
-12	7.7	8.0	8.2	8.4	8.7	8.9	9.2	9.4	9.7	10.0	10.3	10.6	10.9	11.2	11.5	11.9	12.2	12.6	12.9	13.3	13.7	14.2	14.6	15.1					
-11	7.6	9.8	8.0	8.3	8.5	8.8	9.0	9.3	9.6	9.9	10.1	10.4	10.7	11.1	11.4	11.7	12.1	12.4	12.8	13.2	13.6	14.0	14.5	14.9					

		TOP ANGLE (Degrees)												(ມູນແບບວັດ ແຕ່ລະຈຸດປະສານ)											
		30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53
DBH ANGLE DEG ມູນແບບວັດ ຈຸດປະສານ	-10	7.4	7.7	7.9	8.1	8.4	8.6	8.9	9.2	9.4	9.7	10.0	10.3	10.6	10.9	11.2	11.6	11.9	12.3	12.7	13.1	13.5	13.9	14.3	14.8
	-9	7.3	7.5	7.7	8.0	8.2	8.5	8.7	9.0	9.3	9.6	9.9	10.2	10.5	10.8	11.1	11.4	11.8	12.2	12.3	12.9	13.3	13.8	14.8	14.7
	-8	7.1	7.3	7.6	7.8	8.1	8.3	8.6	8.9	9.1	9.4	9.7	10.0	10.3	10.6	11.0	11.3	11.6	12.0	12.4	12.8	13.2	13.6	14.1	14.5
	-7	6.9	7.2	7.4	7.7	7.9	8.2	8.4	8.7	9.0	9.3	9.5	9.8	10.2	10.5	10.8	11.1	11.5	11.9	12.2	12.6	13.0	13.5	13.9	14.4
	-6	6.8	7.0	7.3	7.5	7.8	8.0	8.3	8.5	8.8	9.1	9.4	9.7	10.0	10.3	10.6	11.0	11.3	11.7	12.1	12.5	12.9	13.3	13.8	14.2
	-5	6.6	6.9	7.1	7.3	7.6	7.8	8.1	8.4	8.7	8.9	9.2	9.5	9.8	10.2	10.5	10.8	11.2	11.6	11.9	12.3	12.7	13.2	13.6	14.1
	-4	6.4	6.7	6.9	7.2	7.4	7.8	7.9	8.2	8.5	8.8	9.1	9.4	9.7	10.0	10.3	10.7	11.0	11.4	11.8	12.2	12.6	13.0	13.5	13.9
	-3	6.3	6.5	6.8	7.0	7.3	7.5	7.8	8.0	8.3	8.6	8.9	9.2	9.5	9.8	10.2	10.5	10.9	11.2	11.6	12.0	12.4	12.9	13.3	13.8
	-2	6.1	6.4	6.6	6.8	7.1	7.3	7.6	7.9	8.2	8.4	8.7	9.0	9.3	9.7	10.0	10.3	10.7	11.1	11.4	11.8	12.3	12.7	13.1	13.6
	-1	5.9	6.2	6.4	6.7	6.9	7.2	7.4	7.7	8.0	8.3	8.6	8.9	9.2	9.5	9.8	10.2	10.5	10.9	11.1	11.7	12.1	12.5	13.0	13.4
	0	5.8	6	6.2	6.5	6.7	7.0	7.3	7.5	7.8	8.1	8.4	8.7	9.0	9.3	9.7	10.0	10.4	10.7	11.1	11.5	11.9	12.3	12.8	13.3
	1	5.6	5.8	6.1	6.3	6.6	6.8	7.1	7.4	7.6	7.9	8.2	8.5	8.8	9.1	9.5	9.8	10.2	10.5	10.9	11.3	11.7	12.2	12.6	13.1
	2	5.4	5.7	5.9	6.1	6.4	6.6	6.9	7.2	7.5	7.7	8.0	8.3	8.6	9.0	9.3	9.6	10.0	10.4	10.8	11.1	11.6	12.0	12.4	12.9
	3	5.2	5.5	5.7	6.0	6.2	6.5	6.7	7.0	7.3	7.6	7.9	8.2	8.5	8.8	9.1	9.5	9.8	10.2	10.6	11.0	11.4	11.8	12.3	12.7
	4	5.0	5.3	5.5	5.8	6.0	6.3	6.6	6.8	7.1	7.4	7.7	8.0	8.3	8.6	8.9	9.3	9.6	10.0	10.4	10.8	11.2	11.6	12.1	12.5
	5	4.6	5.1	5.4	5.6	5.8	6.1	6.4	6.6	6.9	7.2	7.5	7.8	8.1	8.4	8.7	9.1	9.4	9.8	10.2	10.6	11.0	11.4	11.9	12.3
	6	4.7	4.9	5.2	5.4	5.7	5.9	6.2	6.4	6.7	7.0	7.3	7.6	7.9	8.2	8.6	8.9	9.3	9.6	10.0	10.4	10.8	11.2	11.7	12.2
	7	4.5	4.7	5.0	5.2	5.5	5.7	6.0	6.3	6.5	6.8	7.1	7.4	7.7	8.0	8.4	8.7	9.1	9.4	9.8	10.2	10.6	11.0	11.5	12.0
	8	4.3	4.6	4.8	5.0	5.3	5.5	5.8	6.1	6.3	6.6	6.9	7.2	7.5	7.8	8.2	8.5	8.9	9.2	9.6	10.0	10.4	10.8	11.3	11.7
	9	4.1	4.4	4.6	4.8	5.1	5.4	5.6	5.9	6.2	6.4	6.7	7.0	7.3	7.6	8.0	8.3	8.7	9	9.4	9.8	10.2	10.6	11.1	11.5
	10	3.9	4.2	4.4	4.7	4.9	5.2	5.4	5.7	6.0	6.2	6.5	6.8	7.1	7.4	7.8	8.1	8.5	8.8	9.2	9.6	10.0	10.4	10.9	11.3
	11	3.8	4.0	4.2	4.5	4.7	5.0	5.2	5.5	5.8	6.0	6.3	6.6	6.9	7.2	7.6	7.9	8.3	8.6	9.0	9.4	9.8	10.2	10.7	11.1
	12	3.6	3.8	4.0	4.3	4.5	4.8	5.0	5.3	5.6	5.8	6.1	6.4	6.7	7.0	7.4	7.7	8.0	8.4	8.8	9.2	9.6	10.2	10.4	10.9
	13	3.4	3.6	3.8	4.1	4.3	4.6	4.8	5.1	5.4	5.6	5.9	6.2	6.5	6.8	7.2	7.5	7.8	8.2	8.6	9.0	9.4	9.8	10.2	10.7
	14	3.2	3.4	3.6	3.9	4.1	4.4	4.6	4.9	5.2	5.4	5.7	6.0	6.3	6.6	7.0	7.3	7.6	8.0	8.4	8.7	9.1	9.6	10.0	10.5
	15	3.0	3.2	3.4	3.7	3.9	4.2	4.4	4.7	5.0	5.2	5.5	5.8	6.1	6.4	6.7	7.1	7.4	7.8	8.4	8.5	8.9	9.3	9.8	10.2

PSP MEASUREMENT FORM

ສວນປ່າໄມ້ Plantation	ຊຸມນິດ ຕະຫຼົກ Stand No.	ຕາມ Plot No. m ² ຂະໜາດ Plot size / / ວັນ, ເດືອນ, ປີ day / month / year
-------------------------	-------------------------------	-----------------	--	---

ຊຸມນິດໄມ້ Species	19... ປີຕັ້ງ Year planted	/ / ກາລສ້າງຕັ້ງ ຕັ້ງປ່າ PSP established ຈັດເທບຄັ້ງ Times measured ຜູ້ຈັດເທບ Measured by
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ຄໍາເພີ່ມເຕີມ Comments
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ຂໍ້ມູນຄ່າຄວາມສູງຂອງໄມ້

Tree Height Data

ຕົ້ນ Tree No.	ເສັ້ນວາງ (cm) GBH	ໄລຍະປ່າ (m) Distance	ມຸມຈັດເທບ ຈາກບ່ອນ 30°→53° Top angle	ມຸມຈັດເທບ ຈາກບ່ອນ 30°→15° GBH angle	ຄ່າຄວາມສູງ ຈາກຕາຕະລາງ Table height	ຄວາມສູງ GBH GBH height	ຄວາມສູງ ຂອງໄມ້ Tree height
.	.	.	0	0	.	+ 1.3	.
.	.	.	0	0	.	+ 1.3	.
.	.	.	0	0	.	+ 1.3	.

ສັນຍາລັກຂອງໄມ້ Tree Codes



tree No.	GBH	tree code
1	.	
2	.	
3	.	
4	.	
5	.	
6	.	
7	.	
8	.	
9	.	
10	.	
11	.	

tree No.	GBH	tree code
12	.	
13	.	
14	.	
15	.	
16	.	
17	.	
18	.	
19	.	
20	.	
21	.	
22	.	

tree No.	GBH	tree code
23	.	
24	.	
25	.	
26	.	
27	.	
28	.	
29	.	
30	.	
31	.	
32	.	
33	.	

tree No.	GBH	tree code
34	.	
35	.	
36	.	
37	.	
38	.	
39	.	
40	.	
41	.	
42	.	
43	.	
44	.	

GLOBAL CASSAVA END-USES & MARKETS: CURRENT SITUATION AND RECOMMENDATIONS FOR FURTHER STUDY¹

**Final report of a FAO consultancy
by
the European Group on Root, Tuber & Plantain²**

Coordination:
Dr. Guy Henry, CIRAD-AMIS (PROAMYL³)

(Draft: 5/3/98, File: ...\\consult\fao\fin-rep4.doc)

Montpellier, 5 March 1998

¹ This study, commissioned by the FAO, represents Phase 1 of a larger study that examines both current cassava uses & markets, and their potential in the future. The latter part (Phase 2) is commissioned by IDRC and IFAD, and is to commence in February 1998, under coordination of dTP, Ottawa, Canada.

² The European Group on Root, Tuber & Plantain (RTB) is a European R&D collaboration platform with current members including NRI (UK), KU Leuven (B), U. of Hohenheim (D), ETH-ZIL (Suisse) and PROAMYL (F).

³ While PROAMYL represented the European Group on RTB in negotiating the contract and coordinating this study, the main authors are Dr. Guy Henry (CIRAD) and Dr. Andrew Westby (NRI).

Table of Contents:

1. Introduction:

- 1.1 Background
- 1.2 Purpose, challenges and limitations

2. Global past trends & current situation by region and/or country

2.1 Aggregate cassava utilisation shares: discussion of 2 reports

2.2 The cassava product portfolio in summary

- 2.2.1 Food products
- 2.2.2 Feed products
- 2.2.3 Starch-based applications

2.3 Africa

- 2.3.1 Fresh, flours & pastes for food
 - 2.3.1.1 Traditional products
 - 2.3.1.2 Use of cassava flours for wheat substitution
 - 2.3.1.3 Fresh roots
 - 2.3.1.4 Cassava leaves
- 2.3.2 Flours, chips & leaves for feed
 - 2.3.2.1 Domestic animal feed
 - 2.3.2.2 International trade of cassava chips
- 2.3.3 Starch-based applications
 - 2.3.3.1 Household starch production
 - 2.3.3.2 Commercial scale starch production
 - 2.3.3.3 Trade in starch

2.4 Asia

- 2.4.1 Fresh, chips & flours for food
- 2.4.2 Chips & pellets for feed
 - 2.4.2.1 Off-farm feeding
 - 2.4.2.2 On-farm feeding
- 2.4.3 Starch-based products
 - 2.4.3.1 Starch in Thailand
 - 2.4.3.2 Starch in Indonesia
 - 2.4.3.3 Starch in Vietnam
 - 2.4.3.4 Starch in China
 - 2.4.3.5 Starch in other Asian countries

Table of contents (cont'd):

2.5 Latin America & the Caribbean (LAC)

- 2.5.1 Fresh & flours for food
- 2.5.2 Chips & leaves for feed
- 2.5.3 Starch-based products
 - 2.5.3.1 Starch in Brazil
 - 2.5.3.2 Starch in Venezuela
 - 2.5.3.3 Starch in Colombia
 - 2.5.3.4 Starch in Paraguay

2.6 European Union (EU) and the US

- 2.6.1 Fresh for food
 - 2.6.1.1 EU imports of fresh cassava
 - 2.6.1.2 US imports of fresh cassava
- 2.6.2 Chips & pellets for feed
 - 2.6.2.1 Supply to the EU
 - 2.6.2.2 Demand in the EU
 - 2.6.2.3 Recent EU trading
 - 2.6.2.4 Prospects for future trading
 - 2.6.2.5 EU cassava chip/pellet regulations
 - 2.6.2.6 Prospects for new entrants to the EU market
- 2.6.3 Starches in the EU
- 2.6.4 Starches in the US

3. Future prospects for cassava utilisation

- 3.1 Food
- 3.2 Feeds
- 3.3 Starch-based applications

4. Issues and recommendations for further study

Acknowledgement

References

Annexes

1. INTRODUCTION

1.1 BACKGROUND⁴:

The development of the Global Cassava Development Strategy was initiated in 1996 at a "brainstorming meeting convened by the International Fund for Agricultural Development. Cassava was recognised by the meeting as a food security and commercial crop that lends itself to a commodity approach to poverty alleviation, given the close connection between the poverty level in many parts of Africa, Asia and Latin America and the role of cassava in these cropping and food systems in countries in these continents. The importance of farming systems issues and market linkages was also stressed. However in order to recognise and meeting the full potential of this crops, a Global Strategy was considered necessary to:

- (i) *identify the opportunities for further public and private investments;*
- (ii) *develop a framework for international technical co-operation for research and for technology transfer based on current constraints and opportunities;*
- (iii) *to identify more cost effective institutional mechanisms for rationalising (and increasing to the extent possible) the allocation of public and private resources for research and investment; and*
- (iv) *set the scene for future debates in global issues.*

The Global Strategy requires a coalition of stakeholders including cassava producers and their organisations, Governments, the donor community, technical and research agencies and their networks, NGOs and their networks and the private sector in order to achieve the objectives set out above.

The Strategy is being developed from a number of country case studies and regional reviews. A review meeting was held in June 1997 where progress was determined and a schedule for completion of the Strategy decided upon. The plans involve preparing a draft of the Strategy and distributing it to regional bodies and stakeholders for comment and modification. A Forum of representatives of all stakeholders will be held in mid-1998 to ratify the final Strategy and develop a plan for its implementation.

At the end of 1997, it was suggested that it would be relevant to prepare an in-depth study on global cassava utilisation and potential for future markets. Its purpose would be to identify and analyze current uses and potential markets for cassava products. This information is expected to serve cassava stakeholders in better understanding the potential of cassava in different end markets..... FAO, together with IDRC and IFAD made the decision to co-fund this study. The activity includes a Phase 1, the subject of this report, concentrating on the current utilisation and markets, and includes recommendations for further study for Phase 2.

1.2 OBJECTIVES, CHALLENGES & LIMITATIONS:

The objectives of this desk review report are:

⁴ This section draws heavily on the paper by Westby et al. (1997).

- (i) *to identify the current situation of end-uses of traditional and non-traditional cassava products and provide an analysis of food, feed and industrial applications;*
- (ii) *to identify geographical regions for potential cassava markets and demand growth; and*
- (iii) *to provide recommendations on which end uses and geographical areas would need further investigations (for Phase 2).*

The challenges of this desk study is to provide as complete a picture as possible given the provided limited resources, and given the inaccessibility or sheer absence of relevant secondary data. Besides the publicly available data and the "grey" literature, most other data need to be mined through internet searches. The latter is extremely time consuming and has the risk of being never ending. While the study's TOR included a suggested table of contents dividing the study by past, current and future markets/usage and product groups, the authors have come to the conclusion that it will be more efficient and more pro-active regarding the pertinent issues for Phase 2, to divide the study by continent/region i.e. Africa, Asia, LAC, EU and US. For each region, past, current and future aspects by product group will be discussed.

2. PAST TRENDS & CURRENT SITUATION OF END-USES

2.1 GLOBAL AGGREGATE UTILISATION TRENDS:

Current global cassava utilisation is 166.5 MMT. Two recent papers have analyzed past cassava utilisation trends (FAO, 1997; Rosegrant and Gerpacio, 1997). The first paper was based on the results of a FAO econometric model, the second paper discusses the results of IFPRI's IMPACT model for root and tubers. While the two sets of input data and time periods used are not entirely comparable⁵, by and large the generated results should be similar. It is surprising therefore, that the basic results, to a large extent are different in magnitude. For example, as shown in Table 1, the world total cassava utilisation annual growth rate for FAO is 2.4%, while for IFPRI this is 0.79%. In spite of these discrepancies, what is important to note, is that during the last decade, Africa's supply increase, in absolute terms, was destined entirely for food utilisation, while the volumes for food utilisation in Asia and LAC, remained at a constant (absolute) level.

Given that existing data bases and macro analyses on cassava utilisation do not give us consistent or conclusive results, it seems more appropriate for this study to analyze more disaggregated data at the country or regional level, for which less questionable information is available. This in turn may give us the opportunity to distill an aggregate picture which is closer to reality. Furthermore, although FAO utilizes a cassava use classification of *food, feed and other*, whereby the processing (starch) falls into the latter class, it seems more efficient and more transparent (especially regarding the increasing use of starch based products), to classify cassava uses by: *food* (traditional: fresh, flours and pastes), *feeds* (chips, pellets and leaf

⁵ The FAO model uses a moving average series from 1982-84 to 1992-94 for cassava products. The IFPRI model uses moving averages from 1981-83 to 1992-94 for cassava and other root and tubers (excluding potato, sweet potato and yam). However, for the latter series the weight of cassava is approximately 94-96% of total. In addition, FAO, follows its standard utilisation classification of *total, food, feed, and other uses*. IFPRI only uses *total, food and feed*. It seems that cassava processing (starches, ...) and waste for FAO is included in *other uses*, while for IFPRI, these are collapsed into the *feed* class.

mixtures), and *starch based uses* (food and non-food sectors). The latter classification has been adopted in this report.

Table 1: Global cassava utilisation trends: comparison of 2 model results

ANNUAL GROWTH RATES (%) Model:	WORLD		AFRICA		ASIA		LAC	
	FAO ¹⁾	IFPRI ²⁾	FAO	IFPRI	FAO	IFPRI	FAO	IFPRI
Total Use								
83-93/82-93	2.4	0.79	4.3	3.95	1.6	0.6	0.2	-0.07
93-05/93-20	1.8	1.68	2.4	2.47	2.5	1.25	1.5	0.78
Food								
83-93/02-93	2.4	-0.71	3.9	0.58	0.1	-1.85	0.2	-1.97
93-05/93-20	2.2	2.01	2.5	2.51	2.0	1.40	0.8	0.26
Feed								
83-93/82-93	1.1	-0.31	7.6	3.75	4.7	-1.60	0.2	-2.10
93-05/93-20	-0.2	0.59	1.8	0.29	2.5	0.13	1.3	1.26
Other Use								
83-93/82-93	4.7	(-0.31)	5.3	(3.75)	6.8	(-1.60)	0.4	(-2.10)
93-05/93-20	3.1	(0.59)	2.3	(0.29)	4.2	(0.13)	3.4	(1.26)

1) FAO (1997)

2) Rosegrant and Gerpacio (1997)

2.2 THE CASSAVA PRODUCT PORTFOLIO: A SUMMARY

2.2.1 Food products:

Most traditional products are included in this user group, since cassava originally was developed for human consumption purposes. In LAC, besides fresh cassava, a large variety of dried, toasted, fermented, etc. cassava products exist. The largest share is made up of fresh cassava (Colombia and Paraguay) and *farinha de mandioca* (Brazil). In Africa, a even larger variety of processed cassava products for human consumption exist (see the section on Africa for further detail). While the primary interest for cassava regards its roots, several traditional applications are used for the leaves, as mostly evidenced in AS-Asia, notably in Indonesia. Furthermore, more recently, cassava leaves are being used (once dried and milled) as an experimental mineral supplement for babies & young children, in NE-Brazil (CNPMF, 1996). Pertinent references on cassava products for food use can be found in various CIAT publications (<http://www.ciat.com/>), in Egbe et al., (1995) and in Dufour et al., (1997).

2.2.2 Feed products:

Most commonly known products are dried cassava chips & pellets. There is a large variety of sizes and forms of chips, especially in Asia (at household level), either peeled or unpeeled. Pellets exist as native (soft, non-steam pressured) or hard pellets (steam pressured). The latter is mainly used for export purposes. In addition, cassava leaves are being used in Asia for small household level fish production, while in Brazil, cassava leaves are being mixed with cassava chips or starch waste, for on-farm pig feeding. Recently, a similar experience has been reported from Nigeria. All possible uses for cassava in animal feeds are extensively discussed by Buitrago (1990) and supplemented in CIAT (1989).

2.2.3 Industrial uses: starches, starch derivatives (and by-products):

Starch or cassava starch, in this context, can be classified according to end-use or to processing technique. A practical classification used by Roper (1996) and by Sansavini & Verzoni (1998) includes 4 main classes: *native starch*, *hydrolysates*, *modified starch*, and *others*. The industries utilizing starch can be basically divided into: food and non-food sectors. As such, starch (lysine, ...) for the animal feed sector, is included as a non-food. The list of industries that are currently using starch is very large since starch is being used in thousands of end-products. A good reference for extensive listing of the sectors are Ostertag (1996), Leygue (1993), Roper (1996) and Gottret et al., (1996). Besides, the internet home-pages of major starch multinationals, like Cargill, ADM, Purac, CERESTAR, CPC, list all possible derived products. Furthermore, a substantial number of modified starches are labeled with codes rather than names (as is the case of cationic starches for the quality paper industry). For the sake of efficiency on the one hand, and data availability on the other hand, this report will mainly deal with starch used in the following sectors (including a non-exhaustive sample of end-products):

Food Sector

- Food processing industries:*
- bakery & pastry products
 - noodles, vermicelli,
 - soups, sauces,
 - icecreams, yoghurts, lactic drinks, puddings, ...
 - processed meats, ...
 - sweets, chocolates, candy, chewing gums, ...
 - marmelades, jams,...
 - canned fruits, juices, ...
 - soft drinks, beers, ...
 - snackfoods,...
 - taste enhancers, colour enhancers,
 - fat substitutes for dietary products
 - alternative protein sources
 - sweeteners,
 -

Non-Food Sector

Paper, cardboard & plywood: - carton, high quality papers, different plywoods, ...

Textile industry:

- fillers, stiffeners, ...
- leather goods

Pharma & chemical industry:- glues, paints, cements,

- soaps, detergents, bleaches, insecticides, ...
- explosives
- oil drilling materials
- biodegradable plastics, polyesters, etc.
- industrial alcohols
- combustibles, ethanol, oils,...
- pharmaceuticals, vit. C, vit. B12, antibiotics, ...
- cosmetics, ...
- water treatment agents
-

Feed industry:

- protein substitutes
- carbohydrate sources

As mentioned before, very few updated and consistent reports exist regarding starch markets. Roper (1996), based on 1991-92 data, refers to a European starch market of 6.1 MMT. Information from the International Starch Institute in Denmark (Thomson, 1997) mentions the EU producing 7 MMT, which is consistent with A.A.C. (1997), but a Cerestar (1997) source notes 6 MMT. Ostertag (1997), using largely 1992 data, calculates a global market of 33.2 MMT, with shares for the US & Canada of 41%, the EU 18%, and Asia 34%. A recent (still unpublished) study by Sansovini & Verzoni, using 1993 data, estimates the world market at 33.7 MMT.

The cassava share of global starch production is estimated by Ostertag (1996) at 6%, but by Sansavini & Verzoni (1998) as high as 10-11%. These conflicting estimates do not contribute much to a clear understanding of the global cassava starch situation. However, it seems more pertinent to analyze the cassava starch actual and potential markets at the disaggregate or country level.

2.3 AFRICAN CASSAVA UTILISATION & MARKETS

2.3.1 Fresh, flours & pastes for food:

2.3.1.1. Traditional products

The majority of cassava grown in Africa is for human consumption (88.7% of production according to FAOSTAT cited in Bokanga 1997). The most comprehensive study of cassava utilisation in Africa in recent years has been the Collaborative Study of Cassava in Africa (Nweke, 1988). Analysis of data from the first phase of this study, a village level survey in six countries (Ghana, Tanzania, Nigeria, Democratic Republic of Congo, Cote D'Ivoire and Uganda), reveals a vast array of products with varying importance. From the initial 233 villages across the six Africa states, 147 different names were used to describe 623 products. For data analysis, these products were aggregated into nine product categories using key processing steps as indicators (Table 2; Natural Resources Institute 1992).

Table 2. Product types by country for the first three ranked products in each of 233 villages, COSCA Phase 1

Product Type	Cote D'Ivoire	Ghana	West Nigeria	East Nigeria	Tanzania	Uganda	Zaire	Total	%
Cooked Roots	35	20	-	11	9	33	-	108	17
Roasted Granules	7	19	18	24	-	-	-	68	11
Steamed Granules	30	1	-	-	-	-	1	32	5
Flours/ Dry Pieces	21	27	17	35	61	52	66	279	45
Fermented Pastes	4	10	19	21	1	-	20	75	12
Leaves	-	-	-	-	1	3	2	6	1
Drinks	-	-	-	-	-	6	-	6	1
Sedimented Starch	22	-	3	3	-	-	-	28	4
Unclassified	-	5	4	4	2	2	4	21	3
Total								623	100

Source: Natural Resources Institute (1992)

[illegible]

As a rule, cassava processing is more sophisticated in East Africa than in West Africa. For example, in Uganda the most important “products” are fresh root and then sun-dried flour. The additional products, cassava beer, distilled spirit and kabalagala, are all produced from the flour. With the possible exception of fresh cassava in some countries, the processing of traditional products is the most important use of cassava across Africa. Future developments in this area will depend on the socio-economic climate and food preferences of consumers. For example, FAO (1997) predicted that the consumption of fresh cassava and products (gari, attieke, fou-fou) were likely to rise in 1997 partly as a result of rising domestic price for cereals, reflecting high import prices and the disruption of marketing systems due to civil strife in some countries.

9

The extent of mechanisation in the COSCA study countries has been reported (Table 3; Natural Resources Institute 1992). Care is needed in interpretation of these data since screw presses and graters are used in gari, attieke and placali processing, which are common in the West African countries. These products do not exist in East and Central Africa and so these forms of mechanisation would not be expected. The lack of mechanisation in the Zairian villages is however worthy of note.

Table 3. Extent of mechanisation in COSCA villages

Country	Mills/grinders	Graters	Screw Press
Cote D'Ivoire	6	4	28
Ghana	24	5	0
Nigeria	26	34	20
Tanzania	9	0	0
Uganda	24	0	0
Zaire	0	0	0
Total	99	43	48

As cassava processing is further mechanised, there may be scope for the introduction of additional pieces of machinery such as that for debarking cassava or roasting gari (see Westby and Cereda 1994). The future development of traditional processing is, however, not only a question of mechanisation; attention has also to be given other issues such as: raw material supply, availability of credit, whether people work in groups or as single entrepreneurs etc. These largely represent the "social content" of technology development. It is already well established that the introduction of machines shifts the responsibility for individual processing steps from women to men (Natural Resources Institute 1992).

Another potential future approach is the development of more convenient forms of traditional products. This approach has been suggested for fu-fu in Nigeria (Sanni *et al.* 1998), where a dried form of the food would have a longer shelf life and be easier to prepare than the current wet paste. It was proposed that this would improve the competitiveness of the product against gari which has become more popular in recent years. Similar approaches may be appropriate for other products such as agbelima and placali. Nweke (1997) proposed that such "ready-to-serve" products had the capability to compete with grains.

2.3.1.2 Use of cassava flours as a substitute for wheat flour

Cassava flour is common in Africa and, provided the quality is high, there is the potential to replace wheat flour in a number of recipes including bread, biscuits, cakes etc. Djoussou and Bokanga (1997) have shown that, with a 15% substitution rate of wheat flour with cassava, Nigeria could save up to US\$14.8 million in foreign exchange annually. US\$12.7 million would go to cassava processors and US\$4.2 million to cassava farmers. Researchers in Ghana (Annor-Frempong *et al.* 1996) have been investigating the use of cassava as a filler in comminuted meat products and they report a potential saving of US\$150/tonne in the final product.

The use of cassava flour in bread was summarised by Bokanga (1997). He points out that wheat imports to the region have decreased, but bread is still largely being consumed. He cites a recent survey in Nigeria and Cote D'Ivoire where it was shown that the quasi-totality of the bread consumed in the survey area was from composite flour (wheat mixed with cassava, sorghum or maize flour). Cassava flour has been added to bread in Cote D'Ivoire since 1982.

Research work at the International Institute of Tropical Agriculture has led to the development of other bakery products using cassava flour as a substitute for wheat. These include doughnuts, cakes, biscuits, croquettes and chinchin. Kapinga *et al.* (1997) adopted a cautious approach to the dissemination of these products in Lake Zone, Tanzania. This involved the following stages: (i) identification of the initial need to diversify cassava utilisation, (ii) a feasibility study; and (iii) an interactive pilot phase where information was obtained on the factors that would facilitate sustainable uptake of the technology.

There was potential for certain new products, but not for others (Table 4). This was reflected in the high take up rates in both the pilot and wider dissemination phases of only certain products. The most effective dissemination route for these products was through Church and womens groups (Kapinga *et al.* 1997). Returns to labour investment when using cassava were significantly improved (Kapinga *et al.* 1998).

Table 4. Most commonly prepared cassava products in pilot dissemination areas of the Lake Zone, Tanzania.

Cassava Product	Number of people still making the product after five months				Total
	Mwanza - Urban (n=17)	Mwanza - Rural (n=11)	Mara Urban (n=5)	Mara Rural (n=5)	
Doughnut	15	10	4	3	32
Cake	3	1	2	4	10
Biscuit	1	1	0	1	3
Chinchin	4	10	2	3	19
Croquette	1	1	0	0	2

Note: Products contained 100% cassava flour.

R: Further detailed market studies are required.

2.3.1.3 Fresh roots

One of the weaknesses of data from the first phase of COSCA was that it did not distinguish between the relative importance of fresh roots and processed products. Cooked fresh roots were recorded as processed products in some but not all of the countries surveyed. The importance of fresh roots can be estimated (in terms of expenditure) from household expenditure surveys such as the Ghana Living Standards Survey (1992). Analysis of this data (Table 5) shows that even within one country there are great differences in the amount and ways in which cassava is consumed.

Cross border trade in cassava products within Africa exists, but there is little data available to quantify it. As an example, it has been reported (Anon. 1997) that a Zambian company bought US\$50,000 worth of fresh roots for processing into flour for export to Angola and the Democratic Republic of Congo. The future expansion of cross-border trade is difficult to predict without a better understanding of the current situation.

Table 5: Home consumption of cassava by region in Ghana taken from Ghana Living Standards Survey (1992).

Average annual per capita value of reported home consumption of cassava (1992 Cedis)			
Region	Roots	Gari	Other forms
Western	8465	424	27
Central	12365	205	77
Eastern	12685	61	332
Gt Accra	227	0	488
Volta	5076	326	3705
Ashanti	6563	3	20
Brong-Ahafo	4697	39	510
Northern	150	9	1690
Upper West	11	0	17
Upper East	0	0	0
Ghana	5858	107	675

The United States and European Union form a large share of the world's import demand for fresh cassava. Supply to these destinations is dominated by exports from Costa Rica. In comparison, African exports are very small. Out of the African exporters, only Ghana is a significant supplier. The potential for export to Europe and the US will be dictated by the price competitiveness of African cassava against Central and South America's competitors.

R: Further info is required regarding its future potential.

2.3.1.4 Cassava leaves

Although the majority of data available for cassava relates to the roots, cassava leaves are very important in some countries. In the Democratic Republic of Congo cassava leaves have greater market value than roots (Lutalldio and Ezumah 1981). It has been estimated that cassava leaves account for approximately 68% of all vegetable output in the country (Tshibaka and Lumpungu, 1989).

R: Further info is required regarding its future potential.

2.3.2 Flours, chips & leaves for feed:

2.3.2.1 Domestic animal feed

Only 1.4% of current cassava production in Africa is thought to be used in animal feed compared with 2.9% in Asia and 33.4% in the Americas (FAOSTAT data cited by Bokanga 1997). In Africa, livestock production is restricted by the distribution of the tsetse fly. The insect thrives in the more humid regions of Central Africa and is responsible for the low per capita livestock populations across the middle of the continent. The areas favouring the growth of root and tuber crops are similar to those favoured by the tsetse fly (Thorne 1992). Cassava is used to a certain extent already in livestock rations in some locations, for example in Madagascar (Thorne 1992). At the household level, cassava peeling are commonly thrown out for animals to feed upon. Many of these animals are free range (for example in Brong Ahafo, Ghana; Gogoe 1996). Little data is available to quantify this use of by-products.

The use of cassava in livestock feed is a potential market opportunity with expanding urban markets and increased demands for meat. Research that has been undertaken has shown that incorporation of cassava into, for example, poultry layer diets in Cameroon, can result into up 41.8% savings in feed costs (Baner *et al.* 1996). The use of cassava in domestic livestock

rations also offers an alternative to exporting cassava chips. Two case studies of the potential domestic use of cassava are presented below.

2.3.2.2 Market opportunities in Zimbabwe

Kleih (1994; 1995) estimated the potential level of commercial/industrial use of cassava in Zimbabwe. There is currently little cassava grown in Zimbabwe, but there is a lot of interest because of recent poor maize harvests. By analysis of the future markets and rapid rural appraisals in potential production areas, the future supplies and demands for cassava were estimated (Table 6). Partial crop budgets calculations were used to show that cassava can compete against other cash crops in communal lands. Cotton, which is the main competing crop, is more profitable on a net income per season basis but less if income per labour day is used as an indicator. Other cash crops (groundnuts and sunflower) and the subsistence crops (maize and small grains) were less competitive using both indicators (Kleih 1995).

Table 6. Demand for cassava products in Zimbabwe (adapted from Kleih 1995)

Sector	Quantity and product required	Fresh root equivalent (tonnes)	Comments
Stockfeed	20,00 tonnes of dried chips or meal in the short term	54,000	Immediate demand from stockfeed manufacturers in Harare, Bulawayo, Gweru and Triangle. Besides the large manufacturers, dried cassava can be sold to commercial farmers and ranches, as well as communal livestock schemes.
	115-118,000 tonnes or dried chips in the medium and long terms	310,000-508,000	
Starch	7,700 tonnes of chips from peeled roots	23,000	Demand is not certain and may only occur medium to long term. The major manufacturer indicated that they will concentrate on maize for the next five years. Dry matter is preferred input.
Flour	500 tonnes of high quality root meal,	2,000	Demand is not certain and may only occur in the long term.
Brewing	10,000 tonnes of dried chips from peeled roots	30,000	Demand is not certain and may only occur in the medium to long term.
Ethanol	240,000 tonnes of fresh roots or equivalent in dried chips	240,000	Demand is not certain and may only occur in the long term once a large scale cassava economy is established. Cheaper processing technologies would be required. 240,000 tonnes could produce 40 million litres of ethanol, equivalent to 13% of current petrol consumption.

2.3.2.3 Cassava for livestock feed in Ghana

The recent expansion of the commercial feed sector in Ghana has increased the demand for maize leading to high seasonal price variations and a need to import maize to cover this shortfall (Hector *et al.* 1996). A feasibility study examining the production, utilisation and cost-benefit of cassava substitution to farmers and poultry producers was carried in December

1995 (Barton *et al.* 1995). It was concluded that cassava chipping could expand market opportunities and improve on financial returns on the crop to farmers. Cassava could have effectively substituted for maize over a six month period in 1995/96 and could have offered a reduction of 10% in comparative feed costs (assuming ration performance was not impaired). Participative research has been initiated to develop suitable cassava chip production systems and confirm the fitness for use of cassava in poultry and pig rations.

2.3.2.4 International trade in dried cassava for animal feed

By world standards, African dried cassava imports were small between 1992 and 1995 (Table 7). The major importing countries (Egypt, Morocco and South Africa), as might be predicted, do not produce significant quantities of the crop. They also experienced an astonishing 99.7% decline by quantity during this period. This may have reflected improved domestically grown feed availability in the major importing countries, or simply a decline in the competitiveness of dried cassava on the international feed markets. Alternatively, the major African importing countries may have implemented feed import substitution programmes.

Dried cassava exports from Africa were relatively stable between 1992 and 1995 (Table 8). However, Tanzania, the major exporter according to the figures, exported a suspiciously constant volume and value of dried cassava between 1993 and 1995. This requires confirmation. Further doubt is cast on the data by considering the study of Ghana.

Table 7. Imports of dried cassava into African countries.

	1992		1993		1994		1995	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
	Tonnes	'000 US\$	Tonnes	'000 US\$	Tonnes	'000 US\$	Tonnes	'000 US\$
Botswana	10	7	63	37	93	31	7	7
Cameroon	0	0	0	0	0	0	17	1
Egypt	27528	3670	52500	6000	0	0	0	0
Kenya	773	114	510	63	9	0	8	1
Morocco	59457	4423	49508	3947	11500	1035	0	0
Reunion	0	0	7	2	0	0	0	0
Senegal	0	0	3	1	30	1	0	0
South Africa	29699	1410	4088	0	0	0	3	4
Zambia	0	-	0	-	0	-	3	-
Africa Total	117467	9624	106679	10050	11632	1067	38	13

Definition: Includes peeled, sliced and sun-dried (cassava chips), as well as ground and compressed cassava (pellets). Used mainly as livestock feed.

Source: FAOSTAT database

Several pieces of ad-hoc information bring evidence to the fact that West African cassava chip exports (to EU) are increasing. This seems to be the case for Ghana, Ivory Coast and Cameroun. Similar information from Nigeria needs further verification. In a further section on the EU pellets imports, further more detailed information follows. One of the major issues facing potential exporters from African countries is the prices paid by importers of the chips. These have been extremely low recently making it difficult for exporters (See Ghana case study as an example). Nweke and Lynam (1996) estimated that only 10% of Nigerian establishments produced chips at less or equal to the monthly mean world market price (FOB) of the commodity in January and February 1996.

Table 8. African exports of dried cassava

	1992		1993		1994		1995	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
	Tonnes	'000 US\$	Tonnes	'000 US\$	Tonnes	'000 US\$	Tonnes	'000 US\$
Cameroon	10	10	1	0	0	0	1	1
Benin	38	5	0	0	0	0	0	0
Kenya	0	0	100	46	116	39	0	0
Madagascar	0	0	5449	237	9327	492	6732	462
Malawi	25	3	0	0	25	3	25	3
Zimbabwe	0	0	0	0	0	0	28	3
Senegal	0	0	0	0	163	2	3	0
South Africa	0	0	0	0	0	0	37	12
Tanzania	32000	3200	21000	1800	21000	1800	21000	1800
Total Africa	32073	3218	26550	2083	30631	2336	27826	2281

Definition: Includes peeled, sliced and sun-dried (cassava chips), as well as ground and compressed cassava (pellets). Used mainly as livestock feed.

Source: FAOSTAT database

2.3.2.5 Case study of chip exports in Ghana:

In 1994 a Ghanaian company started exporting cassava chips to Europe. Export quantities were modest in the first two years of exporting but in 1996, the company claims to have exported 19,725 tonnes. By Ghanaian standards, this represented a significant level of export earnings (Pessey 1997). Supply comes from farmers, who harvest and process cassava into chips. The company established a network of buying points, which collects quantities of chips before sending consignments to Tema port by road or by the lake system, both of which are costly routes of transport. On reaching Tema, inefficient bulk handling facilities add considerably to export costs (Pessey 1997). While f.o.b. prices remained high, the company could afford to pay farmers promptly and adequately. However, in 1997, when EU prices declined to their current low levels (f.o.b. Ghana prices are currently 45% lower than the 1996 level), cash liquidity within the company became a problem. Many farmers remained unpaid, and those that were paid, received low prices. Farmers lost interest in processing cassava chips. The company claims still to export cassava chips, though it has been forced to rationalise its operations (personal communication, Natural Resources Institute, Accra). There is a clear lesson to learn from the Ghanaian experience. High costs of supply must be reduced as quickly as possible: The EU is a very harsh & competitive environment...

While most (West) African countries seem to first target « lucrative » export markets, it seems however more appropriate, to first analyze domestic market conditions regarding its potential for increased cassava utilisation for on-farm or off-farm animal feeding.

2.3.3 Starch-based applications:

2.3.3.1 Household level starch production

The availability of data on household level starch production is very limited. Household level starch production does exist, as demonstrated by the data from COSCA (Table A1), but is probably mainly for local food use.

2.3.3.2 Commercial scale starch production

There used to be a number of cassava starch factories operational in Africa including ones in Uganda, Tanzania and Madagascar. Few of these are now operational and little data is available on their production. An African starch experience comes from Malawi (CFC, confidential report, 1997), where the local paper and cardboard industry is willing to buy up to

1.5 MT of cassava starch (for adhesives) a day, while the confectionary, plywood and food processing industries have also expressed interest to use (local) cassava starches. Similarly, one report from Uganda (CFC, confidential report, 1997) evidences the opportunity for cassava flour to partially substitute for wheat in the manufacturing of baby premixes, biscuits, ethanol and dextrins. The other report, from the same source, describes the possibility for refurbishing an old starch factory for future production of starch, glucose and dextrine for use by the pharmaceutical, food-processing and textile industries. The factory (to be) is envisioned to produce 15 MT/day of starches, based on cassava and corn as the source crops.

R: Data required on current production of cassava starch at household and commercial levels. Assessment of ability (technical and financial) for operators of different scales to enter starch market.

2.3.3.3 Domestic market potential for cassava starch: Case study in Ghana.

Graffham *et al.* (1997) surveyed producers and users of starches and flours in Ghana between February and April 1996. The market for starch within Ghana comprises a number of end users who make use of maize, cassava and potato starch, which is mostly imported. The current market (Table 9) is approximately 4,200 tonnes per annum, which compares well with figures in a survey carried out by Glucoset Limited of Ghana (Anon. 1994). The Glucoset survey also predicted that demand will increase to 5,600 tonnes by 2000. Most users have very high quality specifications with 60% of the market being for modified starches.

Table 9. Market for starch (maize, cassava and potato) in Ghana in 1996.

Sector	Market share (%)	Tonnes per annum (estimated)	Requirements
Textiles	40%	1680	High quality specifications in terms of purity and microbiological quality
Pharmaceuticals	20%	840	Medium specification, require high level of purity and consistent product quality with respect to viscosity.
Paper	10%	420	Low specification, require low fibre and particulate contaminants.
Food	3%	126	High quality specifications in terms of purity, microbiological quality and specialised pasting characteristics for particular products.
Plywood (glue extenders) + others	27%	1134	Low specification, require low fibre and particulate contaminants.
Total		4,200	

The use of starch from locally grown cassava would mean that less material has to be imported. Further work is required to determine whether small-scale processors can produce starch of a high enough quality or whether there are opportunities for large scale processing plants using cassava as a raw material. Bokanga (1997) made some estimates of the potential use of cassava for alcohol and starch in Nigeria. He predicted that one factory consuming 30 tons of cassava chips per day for alcohol could save US\$2.06 million in foreign exchange, with net returns to processors of US\$1.5 million and US\$0.5 million to farmers. Use of cassava for starch (based on an annual production estimate of 200,000 tonnes) would have no forex savings but would result in US\$30.12 million net income to processors and US\$12.5 million to farmers.

2.3.3.4 Trade in starch

A stage on from the use of cassava starch by the domestic food and non-food industries is the export of starch. Data for starch cassava exports are available from FAOSTAT that show that starch to the value of only US\$16,000 was exported in 1995. The major exporting countries were Kenya and the Democratic Republic of Congo. Over the period 1992-1995 Africa was a very minor exporter of cassava starch. The only significant quantity was exported by Egypt in 1993. Since Egypt is not a major cassava producing country, this may have been produced elsewhere. This said, imports were significantly (Table 9) less than exports in 1993.

By contrast with its exports, Africa was a significant importer of cassava starch between 1992 and 1995 (Table 10). Only a small quantity of African imports could have come from African countries because exports were so low. With appropriate development, African countries with potential comparative advantages in cassava starch production may in future be able to supply themselves or other African nations. However, the extent to which intra-African cassava starch trade is possible will crucially depend on the cost of intra-African transport. This potential is worthy of investigation. In terms of imports of other types of starch (wheat; Table A3 and potato; Table A4), north African countries tend to be the largest importers of EU starch. This may reflect their greater level of industrialisation. According to data taken from US Department of Commerce, the US is not a major starch exporter to Africa. No types of starch, other than the those that appear in the tables, were exported from the US to African countries during 1996 and 1997. Cassava starch exports from Thailand for African destinations (non-specified....), between 1993-96, fluctuated between 3,200-12,167 MT/year (TTTA, 1996).

Table 10. African cassava starch imports

	1992		1993		1994		1995	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
	Tonnes	'000 US\$	Tonnes	'000 US\$	Tonnes	'000 US\$	Tonnes	'000 US\$
Congo, Rep.	1	1	4	4	0	0	0	0
Egypt	62	31	113	86	0	0	7	12
Gabon	0	0	160	31	31	6	0	0
Madagascar	12	4	19	8	20	6	0	0
Mauritius	59	22	71	22	66	22	144	74
Morocco	11	20	0	0	0	0	0	0
Mozambique	2800	1100	2700	900	2700	900	2700	900
Zimbabwe	0	0	0	0	3	2	0	0
Reunion	186	82	156	58	178	66	249	120
Rwanda	52	49	52	49	52	49	52	49
Senegal	2	3	1	3	1	3	54	24
South Africa	6263	1523	5692	1209	10050	2118	3124	848
Africa Total	9448	2835	8968	2370	13101	3172	6330	2027

Source: FAOSTAT database.

Although some data have been identified on the current supply and demand for starches in Africa, more are required before recommendations can be given on the future of starch processing. Specifically more data are required on the demands for modified starches and hydrolysis products. An important criterion in the assessment of this market potential will be the ability to produce starches of the appropriate quality for various commercial applications.

2.4 ASIAN CASSAVA UTILISATION & MARKETS

2.4.1 Fresh, chips & flours for food

Most information regarding food use in Asia has very recently been reviewed by Hershey et al., (1998) as part of IFAD's Global Cassava Strategy. Hence, let it suffice here to distill the main pertinent trends of this report and add some complementary information.

Outside of Kerela (India) and isolated mountain areas of Vietnam and China, most cassava in Asia for direct food purposes is first processed. As incomes increase over time, also these areas will reduce their non-processed cassava intake in favor of the preferred rice. On-farm cassava flour consumption, seems to behave similar to non-processed cassava in Asia, as it also substituted for rice as economic conditions improve. Nonetheless, on-farm, in the poorer Asian rural areas (Indonesia, Vietnam, China) cassava may remain as an emergency or buffer crop, in times of rice scarcity. However, this is not the primary nor the preferred use. Off-farm, as experienced in Indonesia (Damardjati et al., 1997), the Philippines and Vietnam (Nghiem, 1993), cassava flour may encounter alternative growth markets, as a cheaper (partial) substitute for wheat in the bread & pastry industries. So far, only isolated experiences have been reported.

R: Further investigation is needed to quantify these potential markets.

2.4.2 Chips & pellets for feed

2.4.2.1 Off-farm animal feeding (national & export):

As extensively reported by Hershey et al, (1998), Henry & Gottret (1996), Henry et al. (1995) and Henry et al (1994), Thailand has been the principal cassava⁶ chip & pellet producer and exporter, for more than 3 decades. As the result from a series of trade policy changes throughout the late 80's and 90's, Thai pellet production and exports have steadily decreased from 7.2 MMT in 1990 to 3.6 MMT in 1996 (TTTA, 1996). Furthermore, the share of Thai chips has become negligible compared to the pellet share. Pellet export prices, as the cause of reduced exports, have behaved irregular. While at the end of the 80's starting 90's the cif Rotterdam pellet price was in the 145-165 US\$/MT range, as EU coarse grain prices started to slide, so did Thai pellet prices. While in 1995, average EU pellet prices rebounded to a US\$ 140/MT level, since, they have slid to a current 1998 price level of less than US\$ 100/MT (fob price European port of DM 170-177/MT). Hence, the Thais have not been able to satisfy their annual export quota to the EU (also due to domestic root competition of the starch industry)..... The future potential of cassava for the domestic feed industry and its competitiveness vis-à-vis domestic or imported corn, needs further study.

Indonesia, as the second largest chip/pellet⁷ exporter has experienced a similar export erosion trend, although regarding much smaller volumes. As will be further elaborated in the

⁶ It needs to be noted that a large share of the by-products from the Thai cassava starch processing industry is used as raw material for the cassava pelleting industry. However, no exact figures on its utilisation rate are available.

⁷ Contrary to Thailand, Indonesia still ships large volumes of chips. Currently, exports are equally divided between chips and hard pellets. The relatively cheaper chips have been used, at times, by other Asian countries for starch processing.

discussion on starch (in Indonesia), the domestic market for Indonesia is of primary importance, especially for starch. While Indonesia has profited from its EU pellet/chip exports until the early 90's, it has actively diversified its market, which currently is almost equally divided by the EU and Asia (Taiwan, Japan, Hong Kong, China,...) and others. Future processing emphasis in Indonesia will further shift to starch rather than chips & pellets..... Little hard information is available regarding future potential of cassava for domestic feed utilisation. This needs further attention.

2.4.2.2 On-farm animal feeding:

Cassava on-farm utilisation for animal feed has been a common practice throughout Asia. However, currently, and especially in the more isolated (non starch industry influenced) areas of Vietnam and China, this activity has received increasing attention (UPWARD, 1996; Hershey et al, 1998; Henry & Howeler, 1996). The explanation is straightforward: as in these countries, incomes rise, protein (especially pork) consumption will augment, especially in the faster developing urban areas. More isolated farmers, that have a tradition of fattening some pigs every year (for Tet celebrations and as a fallback source of capital) with farm produce by-products and roots & tubers, see the rising pig prices and demand, and react by steadily increasing their number of pigs, etc., etc. As large-scale pig production units are still relatively scarce (but increasing rapidly), most pork production, still comes from individual household production. The role of root & tubers has become increasingly important for this particular development process. Additional research is needed to quantify future potential of cassava for on-farm pig feeding. These type of analyses have been included in proposed integrated collaborative projects by national and international agencies in these countries (CIP, 1997).

2.4.3 Starch-based applications in Asia

2.4.3.1 Starch situation in Thailand:

Thailand is the largest cassava starch producer, manufacturing approximately 2 million MT of native and modified starches, of which less than half is exported. Siroth (1997), reports that the industry currently is made up of 52 factories, down from 96 in 1974. The same author reports the domestic cassava starch utilisation, by industry, as follows (% of total 1994: 1,121,625 MT):

<i>Chemically modified starches</i>	<i>25.41%</i>
<i>MSG (80%) and Lysine(20%)</i>	<i>12.10%</i>
<i>Glucose/Fructose syrup</i>	<i>11.97%</i>
<i>Food processing</i>	<i>11.87%</i>
<i>Paper</i>	<i>11.49%</i>
<i>Physically modified starches</i>	<i>7.37%</i>
<i>Sago pearl</i>	<i>3.56%</i>
<i>Plywood</i>	<i>2.14%</i>
<i>Textile</i>	<i>1.86%</i>
<i>Sorbitol</i>	<i>1.55%</i>
<i>Adhesives</i>	<i>1.19%</i>
<i>Others</i>	<i>9.49%</i>

TTTA (1994) reports estimates of annual starch export growth rates for the main starch products between 1987 and 1992 as: native (10.5%), modified (33.8%), sorbitol (48.9%), MSG (12.8%), glucose syrup (9.4%) and sago (8.3%). These figures speak for themselves regarding the dynamics of the Thai starch industry. As the industry becomes more competitive and hence, more secretive, traditional info sources in Thailand (TTTA) are becoming very reluctant in sharing their latest data. The latest (1996) TTTA Annual Yearbook only mentions exports, but no national utilisation information....

1996 starch exports are estimated at 800-900,000 MT. Principal destinations are foremost Japan and Taiwan, followed by USA, Mexico, China, Singapore, Hong Kong, Netherlands, Philippines and Indonesia. It is interesting to note that even with the very steep EU tariffs, still 28,577 MT of starch was exported to the Netherlands! This is yet another indication⁸ of the competitive low price of Thai starch, that during 1996 averaged US\$ 280-300/MT versus EU potato starch at US\$ 600, while during the year dropping to US\$ 550/MT, due to favorable EU export subsidies (while US corn starch was US\$ 300/MT). The latest Thai starch industry information (31/1/98) mentions a "Super High Grade Starch" price of US\$ 240/MT fob Bangkok (TTTA, 1998).

The TTTA (1996) source also notes an envisioned 1997 (starch) export target of 955-970,000 MT, of which 30% dextrins and modified starches, and 70% native starch (p.37). Internal TTTA activities point towards a growing export market interest for Soviet Republic and China. Additional export opportunities for Japan are totally policy dependant, and as yet, unclear to predict.

While traditionally, the export market has constituted the primary Thai objective, several reports (Titanapawatanakun, 1997) point out the growing importance of the domestic market (as another means for market diversification). The author estimates that for the food sector, MSG and lysine demand will grow fastest, while in the non-food sector, it will be paper and other industrial uses (p.63). However, with the (unforeseen?) current financial crisis, these earlier assessments may need to be revised.

R: Further data is needed regarding domestic and export starch market potential.

Several Thai research groups with government and private industry support, have undertaken considerable research projects regarding new cassava starch based product formulation (ethanol, SCP, food colorants, starch based plastics,...) starch waste valorisation, improved cassava varieties, etc. (Sriroth, 1997; Ratanawaraha et al., 1997). Furthermore, Maneepun (1997) mentions the following "new promising uses for tapioca starch", as: (i) improved quality and cheaper maltose syrups for brewery industry, (ii) maltodextrins

⁸ The current financial and economic crisis in Thailand (and in SE-Asia as a whole), has many serious negative implications for the country, its economy and its people. However, as regards cassava product exports, the huge devaluation of the Baht (currently 54Baht= 1US\$, compared to 26 Baht, less than a year ago), should have significant positive repercussions for the international competitiveness of Thai cassava based products, such as starch. Since most of cassava starch production and processing inputs are non-imported, domestic factors (land, labor), that have risen only marginally in price, cassava product prices have become relatively cheaper, allowing for higher profit margins (for exporters, if at same export prices) and/or increased export market expansion (at lowered prices).

manufactured from physically modified starch (rather than chemically modified), for use as fat replacers, and (iii) cyclodextrins for food and pharmaceutical uses (p. 81).

2.4.3.2 Starch situation in Indonesia:

Traditionally, Indonesia's primary starch market has been the national market (Henry et al., 1995), principally being used for the manufacturing of food snacks i.e. krupuk,... However as the industrial and economic development has steadily increased, other uses (also in the non-food industries) have become important. A study by Gunawan (1997) notes that in 1992, "direct" cassava consumption was only 21.5% of total supplies (p.35), and that about 34-35% of total cassava available, was processed in medium and large scale processing industries, and 45% was used in households, mini and small industries, and non-formal sectors (p.36).

Cassava processing includes animal feed (chips/pellets) and starches. Due to decreased EU cassava prices on the one hand, and increased domestic (and foreign) cassava demand, Indonesia's chip/pellet exports have decreased from 1.2 million MT in 1990 to 600,000 MT in 1996 (FAOSTAT, 1997). Gunawan (1997) notes that "...domestic demand has increased tremendously because cassava products have many different (domestic) uses such as feed, plywood industry, and glucose and fructose industries" (p.39). In addition, confidential information from the US private industry (personal communications, E.Tupper, 1997) reports that currently the Indonesian annual per capita paper consumption⁹ is at 20 KG, with an estimated annual growth rate of 14%. At an average inclusion rate of 35-45 KG of modified starch per ton of paper, this presents a significant derived demand growth potential for cassava (modified) starch in Indonesia. Currently, the larger share of the "more sophisticated" starches is being imported in Indonesia, mainly from the US and Thailand. However, during 1995-97 (up to the financial crisis) significant new investments (both foreign and national) have been made in the construction of large-scale vertically-integrated factories for modified starches manufacturing (Personal communications, P. Tremprom, 1997), indicating a trend towards increased self-sufficiency regarding up-scale starch production. The bottomline is that currently, no reliable and updated data exists regarding Indonesia's starch production, nor its starch utilisation shares, by industry.

R: collect updated information regarding starch industry and its utilisation!

2.4.3.3 Starch situation in Vietnam:

Cassava starch production in Vietnam, before the start of the 90's consisted largely of small household level processing units in addition to several state-owned (run-down...) larger scale units (Thang Ha et al., 1997; Ngiem, 1993; Chien, 1997), mainly producing dry and wet native starch (for noodles, cakes, alcohol, ...) and to a lesser extent maltose (for candy manufacturing, ...). Starting the 90's following "the run for cheap local labour and inputs, coupled to expanding domestic markets", large scale modern cassava starch processing factories were constructed in the major cassava production areas of Southern Vietnam. While in the beginning these were largely joint ventures with Japanese, Korean and Taiwanese multinationals (VEDAN, Ajinomoto, AAA, ...), during the second half of the 90's, local Vietnamese private factories sprung up, in addition to joint ventures with major European and Thai starch companies (PROAMYL, 1997-98; Henry et al., 1995). Limited and ad-hoc

⁹ Compared to the US with 332 KG (1% growth) and Japan with 180 KG (6% growth).

information (personal communications, J. Wang, 1996) points to the fact that from the start, MSG has been the primary product market objective of these new factories (for both national and export markets). However, the product portfolio seems to have changed since the mid-90's (This needs to be investigated since no new data exists).

During the early 90's a cassava starch market assessment was conducted (Thang Ha et al., 1997), showing that the 1992 national cassava starch production was around 90,000 MT. And projected to reach 200,000 MT by the year 2000 (mainly due to increases in MSG production¹⁰). If Vietnam would follow similar industry trends as in Thailand and China, one would expect increased productions of, especially, hydrolised and modified starches in the future.

R: collect updated information regarding starch industry and its utilisation!

2.4.3.4 Starch situation in China:

Data on (cassava) starch in China before the 90's is, at best, sketchy and mostly in Chinese. A first post-80's assessment, though still in Chinese, was written up by Shu Ren and Henry (1993), followed by English and up-dated versions by Shu Ren and Henry (1996) and Shu Ren (1997). These publications report that in 1992, cassava starch production in South China was estimated at around 200,000+ MT, based on a regional availability of 1.2 million MT of chips¹¹. For the major 10 factories in Guangxi alone, an annual starch output of 80,000 MT was calculated. At that time, the cassava starch product portfolio included: native starch, fructose, sorbitol, mannitol, maltol, alcohol, MSG, citric acid, denatured starch, glucose and glucose syrup. For 1996, Henry (1996) reports that the Guangxi (as the most important cassava starch producing province¹²) starch industry was made of 150 factories with an installed capacity of 3000 MT/day, producing 280,000 MT. The industry output consisted of roughly 10% modified and hydrolized starches, and 90% native starch. The same source reports that the industry's annual growth rate estimation was >16%, especially regarding the chemically modified starch supplies.

As referred to in earlier sections, during the last 5 years, the Chinese (cassava) starch industry has enjoyed significant attention from national and especially foreign investors. Henry and Howeler (1996) already noted the industry's trend towards new or refurbished large scale factories at a cost regarding small scale units and old-fashioned large state-owned factories. A report by Howeler (1997) mentions the construction of a series of 5 large-scale new starch factories for the production of bio-degradable plastics. Four of these are already in operation in the provinces of Guangxi, Shandong, Jiangsu and Xinjiang. A fifth is being constructed in Hainan. At least 2 of these factories will use cassava as the principal source crop (p.4). More

¹⁰ MSG industry information points out that Taiwan as the world's number one MSG consumer, consumes an average 1 Kg/year/cap. Even at a conservative rate of 0.5 KG/yr/cap, the domestic Vietnamese MSG consumption could be 60-70,000 MT per year by the year 2000 (personal communications, J. Wang, 1995).

¹¹ It is pertinent to point out that, contrary to most other countries, Chinese (and to some extent, Vietnamese) cassava starch processing depends to a large extent on cassava dried chips as raw material. For further information on this, see Henry and Howeler (1996).

¹² For additional more detailed 1994 primary information on the cassava processing industries of Guangdong, Guangxi and Hainan, see the report of a RRA in S-China by Henry and Howeler (1996).

recent, but still unpublished¹³ information validates the continuation of this upscaling trend. Unfortunately, this latter information does not include a quantification of the industry's product utilisation shares, nor expected growth rates.

R: Further investigation regarding starch utilizing industries & growth rates is required.

2.4.3.5 Starch situation in other parts of Asia:

In the Indian state of Tamil Nadu, there exists a large concentration of small to medium scale cassava starch and sago producers (Shegaonkar, 1994). Salem district alone, with roughly 720 units, represents 80% of the states output. Total Indian cassava starch and sago output is estimated at 200-300,000 MT. The share of sago versus starch is unknown, neither the utilisation rates for food and non-food sectors. Additional information seems to be needed. Apart from India, the Philippines has had some cassava starch extraction operations. Most starch is imported from the US, Thailand and the EU. Contradicting sets of information exist about new cassava starch investments (by San Miguel) and the success of these. Again, better information is required.

R: Further investigation on starch industries in India & the Philippines is required!

2.5 CASSAVA UTILISATION IN LATIN AMERICA & THE CARIBBEAN (LAC)

2.5.1 Fresh & flours in LAC:

Past cassava fresh & flour trends and current situation in LAC have been extensively analysed and reported by, among others, Henry & Gottret (1996) and Hershey et al., (1998). Suffice it to point out that, consumption of fresh cassava in Colombia and Paraguay, and farinha in NE-Brazil will increase with decreasing cassava prices (relative to its major substitutes) in rural and urban areas, for the lowest income groups. Furthermore, in NE-Brazil, studies (Henry, 1996a) have shown evidence, that urban consumers (on the average) were willing to pay more for better quality farinha. This points out that higher quality cassava products may expand traditional demand in these areas. The traditional farinha de mandioca industry in Southern Brazil has been under increasingly heavy competition (for raw materials) by the growing starch industry. Drought conditions in NE-Brazil have boosted the demand for farinha (from the South) during several years now, but this is not sustainable. At this moment, it is not clear what this industries future will be (CERAT, 1997).

In Colombia, Peru, Brazil (Ceara) and Ecuador, integrated cassava project experiences, show the (limited) potential of cassava to partial substitute wheat flour in bakery, pastry and snackfood industries (Ospina et al, 1997; Eguez, 1997; Henry, 1996a). The conditions to benefit from this potential, however, are very site specific and require detailed feasibility studies.

2.5.2 Chips & leaves for feed

Ospina et al., (1997), Henry et al. (1994) and Hershey et al. (1998) have extensively reported on the cassava chip experiences and its future potential for animal feed in Brazil and

¹³ Proceedings of the International (Cassava) Starch and Starch Derivatives Conference, held in Nanning, China, 4-11 November 1996, are still in the process of translation and editing (in collaboration with NRI and CIAT).

Colombia. Gottret et al. (1997) reports a current demand potential (by the feed industry) in Colombia of > 500,000 MT per year (and increasing). Similar and higher figures have been reported for Ceara state of Brazil (Henry, 1996a), depending on the cassava inclusion rates. In Ceara, the potential demand (for chicken and pig feed rations) is augmented by the demand from dairy farmers (for supplementation with cassava chips during the dry season).

2.5.3 Starch-based applications in LAC

2.5.3.1 Starch situation in Brazil:

Cassava starch production increased from 200,000 T in 1990 to approximately 300,000 MT in 1997 (Vilpoux, 1997/98; Carioca et al., 1996). Roughly 70% of Brazil's starch utilisation is based on domestic corn starch, bringing the total industry, currently, at an estimated 1 million T/yr (Vilpoux, 1998). Hence, Brazil's starch expansion has been typically corn-based. Corn starch manufacturing is concentrated with 2 large international (of US origin) companies: CPC International/Refinacao de Milho Brasil, and Cargill, both based in Southern Brazil. The cassava starch industry represents small to medium sized companies, distributed in the states of Sao Paulo, Minas Gerais, Sta. Catarina, Parana (and lately also moving into Mato Grosso do Sul).

Table 11 : Brazilian starch and starch derivatives utilisation, by industria sector, 1997 (MT)

Starch type	Food sector				Paper sector		Textile sector	Other sectors	Total
	sweeteners	bakery pastry	powder products	others	paper	cardboard			
Native starch	2.100	26.500	93.000	109.100	66.300	43.500	20.000	77.000	437.500
Modified									113.250
Acid modified	2.600			1.500	29.900	4.300	30.000		68.300
Cationic					1.800	200			2.000
Anfoteric					24.300				24.300
Dextrins/pregel.			100	300	100	50	100	18.000	18.650
Hydrolised									472.200
Glucose syrups	141.200	800	3.100	30.400			200	1.000	176.700
Glucose powder	200	100	300	5.100			100		5.800
Maltose syrups				271.500					271.500
Malto dextrins	400	300	2.800	14.400			300		18.200
Total	146.500	27.700	99.300	432.300	122.400	48.050	50.700	96.000	1.022.950

Source : Vilpoux (1998)

Current utilisation of starch is detailed in Table 11. This shows 69% of total starch for the food sector, 16.7% for the paper industry, and 5% for the textile industry. It also shows that 43% is native, 46.2% is hydrolysed (sweeteners), and 11% is (other) modified starch. Vilpoux (1998) notes that in 1997, the food industries that increased their starch utilisation the most, where frozen and dehydrated foods sectors (with 18.2%). Furthermore, the same source notes that the future starch demand growth (modified and native) in the food sector will be especially for the ready and semi-ready product lines. Other US private sector information (PROAMYL, 1996) notes the potential increasing demand for cationic starches for the high quality paper industry.

2.5.3.2 Starch situation in Venezuela:

Little hard data exists regarding the cassava starch situation in Venezuela. Scattered first hand info reports that there currently exist 2 large scale integrated (with root production) starch factories. One of these, operates a 7,000 ha cassava farm, partly irrigated, with an average productivity of 25-30T/ha/yr. The roots are processed into native starch and Glucose Syrup. While the latter represents still a small share, the immediate objective is to increase this product output. The primary market is Venezuela, but native starch exports for the Colombian paper industry have also been reported (at a very competitive price vis-à-vis Colombian starches). The main starch source in Venezuela remains corn starch, mostly imported from the US.

R: Primary (starch) utilisation & market data collection is recommended.

2.5.3.3 Starch situation in Colombia:

The main cassava starch products in Colombia are sour starch and native starch. Some sketchy information reports about recent investments in the department of Cauca for a cassava based glucose syrup factory (Gottret et al., 1997). However, no data can be had on production or capacity figures. The cassava sour starch production is mainly concentrated in the Cauca Valley with a total average production of..... from approximately 200 small-scale processing units. Several larger units producing native cassava starch operate in the Atlantic Coast region. Colombian starch utilisation is principally (still) satisfied by starch imports from the US (corn), Venezuela (cassava), Brazil (cassava/corn), and sometimes from Ecuador (cassava). Several corn source based starch factories (Maizena) have existed, but these seem to be in the process of closing down (needs to be confirmed). Gottret et al., (1997) reports the relatively high prices of Colombian cassava based starch. Colombian native starch priced (1996) at US\$500-550/MT versus imported corn starch at US\$ 450-480/MT. At these prices, Thai and even Brazilian starch could possibly imported at a significant profit. It needs to be noted that the Colombian starch market is in the hands of only a very few operators, dictating imports and market prices.

R: Starch utilisation shares by type and industry needs to be collected.

2.5.3.4 Starch situation in Paraguay:

Very little hard data on cassava starch is available for Paraguay. Henry & Chuzel (1997) have noted that small volumes of cassava starch have traditionally been manufactured in small-scale household processing units, for manufacturing of "chipas", a typical snack. However, more recently, growing interest exists from Brazilian starch manufacturers, across the border (Parana and Mato Grosso do Sul), for joint-venture investments in large scale cassava starch manufacturing, taking advantage of relatively lower land and labour prices (This information needs to be confirmed and quantified). Most starch utilised in Paraguay currently, originates from Brazil, and to a lesser extent from the US (corn starch).

R: Updated info on new starch industry investments are needed.

2.6 CASSAVA UTILISATION IN THE EUROPEAN UNION (EU) AND THE US

2.6.1 Fresh for food:

Table A4 summarises EU fresh cassava imports for the last five years. Note that the figures for 1993 and 1994 relate to the EU 12, while 1995/96/97 figures relate to the EU15. No data is currently available to assess how much more cassava was imported to the EU as a result of Austria, Sweden and Finland's entrance to the EU. However, none of these countries has large ethnic populations from developing countries (those most likely to consume fresh cassava) and consequently we can safely assume that the enlargement of the EU had little effect on EU fresh cassava imports. The same table indicates that imports have increased both in value and quantity over recent years. Costa Rica dominates supplies, while Ecuador, Surinam and Ghana supply much smaller though still significant quantities.

In 1997, the UK imported approximately 940 tonnes of fresh cassava (estimated from data supplied by the Home Grown Cereals Authority, UK). At 23% of the estimated 1997 EU imports, this figure indicates that the UK is one of the major buyers within the EU. Since consumers in the UK tend to come from ethnic minorities, the market size is limited. Cassava enters the country either as fresh whole roots, which have been preserved in clear wax and fungicide, or as frozen pieces, which arrive in refrigerated containers. The UK market is currently oversupplied. Traders either predict a decline in the market or at most, a continuation of the current level of sales (personal communications, various traders, New Spitalfield Market, London). Prospective entrants to the EU market would have to be competitive with exporters from Costa Rica, who operate highly organised market channels.

US Department of Commerce trade figures summarised in Table A5, reveal significant imports of cassava to the US. The figures relate to cassava, frozen, fresh or dried. However, the US imports either very little or no dried cassava (personal communication, Linda Wheeler, USDA Foreign Agricultural Service) and so the figures in the table can be assumed to relate almost entirely to fresh or frozen cassava.

2.6.2 Chips & pellets for feed:

The European Union feed market for dried cassava is well established. European feed millers buy cassava pellets and chips as substitutes for feed grain, basing their purchase decisions on cassava's relative price competitiveness. To understand what determines cassava's competitiveness, a review of supply and demand influences is required.

2.6.2.1 Supply to the EU

The EU's major suppliers of feed cassava are, in order of importance, Thailand and Indonesia (FAO Food Outlook, various issues). Both countries predominately supply cassava in the form of pellets. EU feed cassava imports are regulated by quotas but since neither Thailand nor Indonesia have exceeded their quotas over recent years, the quotas have not directly influenced supply. However, the stock-check system which the Thai government uses to allocate EU quotas, has tended to decrease competition among exporters. The system grants export licenses on the basis of past export performance and current stockholding, thereby discouraging new exporters from entering the market. Rather unsurprisingly, a clear relationship exists between the size of the cassava harvest in Thailand/Indonesia, and the quantity of dried cassava which is available for export. Both countries have domestic industries which demand large quantities of cassava. Thailand in particular has recently followed a policy of promoting value added cassava processing, thus creating a significant cassava starch industry (personal communication, Trakulken Feed, Rotterdam). With such

large domestic demand, anything which influences the size of the Thai/Indonesian cassava harvest has an impact on supplies of cassava pellets to the EU. Chief among these influences is of course the weather.

2.6.2.2 Demand in the EU

To make cassava a suitable substitute for feed grains, it must be mixed with a source of protein. Soymeal is commonly used in this role. When deciding whether or not to buy cassava, feed millers compare the price of the cassava/soymeal mix with the price of feed grains. Consequently, soymeal prices affect the demand for feed cassava. For instance, high soymeal prices tend to reduce demand for cassava. Among other influences, feed grain prices in EU are affected by international feed grain prices and the size and quality of the European grain harvest. International feed trade is dominated by maize. The US and Argentina are the world's largest maize exporters. To a considerable extent, supply conditions in these two countries determine world maize prices.

Grain harvests in Europe are affected by weather conditions and European Union agricultural policies. The weather not only affects the size of the European harvest but also its quality. During ripening, adverse weather conditions decrease grain quality, and thereby increase the quantity of grain which is available on the feed grain markets. In recent years the EU has steadily decreased the percentage of arable land which qualifies for "set-aside" payments. Under this scheme, farmers are paid to take land out of production. The reduction of set-aside has effectively increased recent EU grain harvests. International freight rates and the fortunes of the EU livestock industries also influence the demand for feed cassava.

2.6.2.3 Recent EU Trading

At 3.4 million tonnes, EU imports of dried cassava in 1997 were only marginally lower than the corresponding figure for 1996. However, dried cassava *prices* reached a ten year low. The 1997 January to September average dried cassava price was US\$110/tonne, down US\$42 from the 1996 average (FAO Food Outlook, November 1997). The '97 price reflected the following:

- Low EU grain prices. In 1997 the area on which EU farmers were allowed to claim subsidy under the set-aside scheme was reduced from 10% to 5%. This stimulated production and placed downward pressure on EU grain prices
- High soymeal prices. From 1990 to 1995 average annual soymeal prices (c.i.f. Rotterdam from Argentina) were approximately US\$200 per tonne. In 1996 and 1997, prices were US\$268 and US\$279 per tonne respectively (FAO Food Outlook, November 1997)
- Less than expected demand for cassava from the EU pig industry (caused by the outbreak of swine fever in several EU countries).

In early 1998, cassava pellets were trading at approximately US\$100 per tonne (personal communication, Alfred Toepfer International GmbH, Hamburg). Reacting to low export forecasts, the Thai government suspended the stock-check system during 1997, thereby increasing competition among dried cassava exporters. This weakened the Thai exporters' collective bargaining position.

According to recent analysis conducted by DG-VI of the European Commission (Prevost 1997), the average annual prices of cassava-soymeal mix and barley have been equivalent for the past two years. Such averaged figures disguise weekly changes in relative competitiveness. However the message is clear: Against high soymeal prices and decreasing barley prices, cassava has only maintained its competitiveness by becoming cheaper.

2.6.2.4 Prospects for future trading

1998 promises to be an interesting year for dried cassava trading. The drought affecting much of South-East Asia has led analysts to predict low fresh cassava harvests. In Thailand, the harvest prediction is approximately 13.5 million tonnes, six million tonnes lower than the 1997 harvest (personal communication, Alfred Toepfer International GmbH, Hamburg). In Indonesia, demand for cassava as a food (starch) will probably take precedence over dried cassava exports in 1998.

Tight supply in the Far East will meet tight demand in the EU. EU dried cassava prices continue along a low track, while large EU grain harvests are expected yet again to suppress feed grain prices. Moreover, Argentina and the US are expecting bumper maize harvests. If this happens, imported maize may once again become competitive in the EU feed ingredient markets. Despite this situation, EU traders are currently taking out future contracts on dried cassava shipments, in the belief that large soybean harvests predicted for both the US and Brazil will reduce soymeal prices later in the year (personal communication, Alfred Toepfer GmbH, Hamburg).

In October 1997, EU barley prices dropped below their intervention price and thus triggered intervention buying by the EU. Such buying will probably continue well into 1998 (personal communication, EU Interventions Board, Reading, UK). Intervention buying effectively establishes a floor price in the EU barley market. 1998 is therefore unlikely to witness further barley price decreases. Bearing in mind that imported maize prices will probably decline in 1998, maize prices, rather than barley prices, may become more relevant for comparisons between the price of cassava/soymeal mix and the prices of its cereal competitors.

2.6.2.5 EU Dried Cassava Import Regulations

At the end of 1997, the European Commission extended its import quota arrangements for Thai cassava and cassava products. As before, the quota is limited to 5.5 million tonnes. Indonesia and China have separate quotas, both considerably less than the Thai quota. Other WTO members share an import quota of approximately 145,000 tonnes, while non-WTO members share a smaller quota. All imports of dried cassava attract a 6% ad valorem EU import duty. In principal, ACP countries enjoy privileged access to EU cassava markets. In practice, such access has been less favourable than the access which is allowed under normal EU trade provisions (personal communication, DGVI of the European Commission, Brussels). This situation may change as new ACP/EU agreements emerge.

2.6.2.6 Prospects for New Entrants to the EU Feed Cassava Market

The foregoing descriptions of EU feed cassava trading illustrate that the market is complicated and unpredictable in the long term. However, trading has existed for many years and will doubtless continue for many more. Prospective entrants to the market should therefore not be discouraged. However, they must prepare themselves both for stiff competition from South-East Asia and for mixed trading fortunes on the EU market.

2.6.3 Starch situation in the EU:

1994 EU starch production was estimated at roughly at 6 MMT. By 1997, this is estimated at 7 MMT (AAC, 1997). According to the same source, the principle starch source crops are corn (51.5%), wheat (25.5%) and potato (23%). During the last 3-4 years, the share of corn has increased significantly. A recent private industry source, noted by Sansavini & Verzoni (1998), estimates that the EU starch output includes 52% sugars, 28% native starch and 20% modified starches. This seems roughly in accordance to Roper's 1994 and AAC's 1997 (51%, 27.5% and 21.5%, respectively) estimates. The three sources are in agreement about the EU starch utilisation, by industry, as:

<i>Sweets & drinks:</i>	<i>33-34%</i>
<i>Processed foods:</i>	<i>21-22%</i>
<i>Pharma & chemicals:</i>	<i>15-16%</i>
<i>Paper & corrugating:</i>	<i>27-28%</i>
<i>Feed:</i>	<i>2%</i>

Through import tariffs and quotas, the European starch market is highly protecting its national industries from foreign competition. Nonetheless, there exist an ACP-countries quota of 25,000 MT, that includes Thailand to annually export 10,000 MT to the EU. In recent years, the full quota has not been satisfied by Thailand (Coccia, 1998). Regarding imports above this quota, Coccia (1998) cites "The International Custom Journal of the European Union" (1994-95) tariffs as follows:

A. Duty of ECU 150 /ton within the limit of the annual tariff quota of 8000 tons of manioc (cassava) starch intended for the manufacture of :a) food preparations put up for retail sale and falling within heading N.o 19.01 , or b) tapioca in the forms of grains and pearls, put up for retail sale and falling within heading N.o 19.03.

B. Duty of ECU 150 per ton within the limit of an annual tariff quota of 2 000 tons for manioc (cassava) starch intended for the manufacture of medicaments falling within the heading n.o 30.03 or 30.04. Qualification for this quota is subject to conditions laid down in the relevant Community provisions.

However, Coccia (1998) also notes, that the document titled: "The Results of the Uruguay Round", WTO-World Trade Organization ,1996 reports much higher tariffs than those published in the Custom Journal. In fact, for cassava starch, flours and products rate of duties are as follows:

a. For Cassava Flour , Tariff code 1106.20 ,the base rate of duty is of 204 ECU/ton and will be reduced to 131 ECU /ton , by the year 2004.

b. For Cassava Starch , under tariff 1108.14 , the base rate of duty is 260.Ecu/ton and will be reduced to 166 ECU , by the year 2004.

c. For tapioca , under tariff code 1903.01 , the base tariff rate is 10% ad valorem + 236 ECU /tons to be reduced to 6.4% + 151 ECU /ton.

Nonetheless, as export data series from the US show (USDA-ERS, 1997), small volumes of US corn starches (3-4,000 MT/YR) are imported to the EU, mainly to the UK and the Netherlands. In addition (as noted in a later section), Thailand exports considerable volumes of cassava starch above its allotted (10,000 MT) quota, especially to the Netherlands.

Total EU starch exports in 1996 are estimated at 1.1 MMT (AAC, 1997). The shares of native, sweeteners and modified starches of total exports, were 45, 25 and 30%, respectively. EU potato starch exports increased from 122,981 MT in 1990 to 292,142 MT in 1996, an increase of 42%. The estimated starch exports value over the same period increased by 31%. 1996 EU potato starch exports were valued at 121.2 milion ECU (EUROSTAT, 1998). Principal destinations of EU potato starches were: US, Mexico, Thailand, Japan, Taiwan, Hong Kong and South Korea. Especially the SE-Asian countries import increasing volumes.

While European starch multinationals are relatively well protected from cassava starch imports from Asia (although they still want higher import protection plus higher export refunds...), they all are increasingly involved in both vertical and horizontal integration¹⁴ with cassava and corn starch based industries in Asia, and to a minor extent in LAC. Countries of particular interest are Thailand, Indonesia, China and Vietnam (and Cambodia). Hence, executives with Avebe, Roquette, Amylum, have been scrambling during the last several years, to learn more about the basics of cassava... (PROAMYL, 1997-98; CERAT, 1997) and to analyzing the comparative advantages of starch factory construction in North vs. South Vietnam vs. S-China vs. Thailand (vs. Brazil vs. Venezuela). While most emphasis has been on cassava as the "hot new" starch source crop, new corn starch joint-ventures¹⁵ in Asia are also being considered. Besides, starting the early 90's, an increasing number of joint ventures of molasses/cassava sourced starch manufacturing are occurring between Japanese, Taiwanese, Korean and Thai multinationals with local investors in China and Vietnam i.e. Ajinomoto, VEDAN, AAA, VETHAI, (Henry, personal observations, 1996-97).

R: Updated info on starch industry utilisation shares (by type of starch) is required.

2.6.4 Starch situation in the US:

While the US (and Canada) do not use cassava as a starch base, but mainly corn (or molasses), some understanding of its industry is important for the following reasons: (i) US

¹⁴ Information has also been found about a major joint-venture of Cargill with PURAC (daughter of Dutch-based CSM) in Nebraska, US, for the production of lactic acid (USDA-ERS, 1997), evidencing a US-European integration aswell.

¹⁵ Sansavini & Verzoni (1998) cite a CERESTAR source regarding a new 350,000 MT corn starch factory in Jilin province of China, as a joint venture between the Jifa Group and CERESTAR, for a total investment of US\$ 100 million. Production of native starch, modified starch, malto-dextrins, maltose, protein powder, glucose, isomaltose, vitamin C, ... are to be envisioned (Jifa Group Corporation, home-page, 1998).

corn starch makes up the largest global volume of starch (& derivatives), directly competing with potato, wheat and cassava starches; and (ii) the fact that there is evidence of increasing horizontal integration of US traditionally corn-based starch companies, through joint-ventures, into (national) cassava-based starch companies in SE-Asia and LAC. This trend is similar to what is happening with the major European starch multinationals (PROAMYL, 1997-98).

The main US corn-based starches & derivatives include: native, modified starches, sweeteners (HCFS), ethanol, industrial alcohol, citric acid, lactic acid and lysine. USDA-ERS (1997) data shows the following US market demand for some of the "hottest" product groups:

<i>Product</i>	<i>1996/97 volume (000MT)</i>	<i>1996/97 value (million US\$)</i>	<i>future growth</i>
<i>sweeteners (HCFS)</i>	<i>14,900</i>		<i>2-3% annually</i>
<i>ethanol</i>	<i>2,580</i>		<i>4-6% (depends)</i>
<i>citric acid</i>	<i>240</i>	<i>340-380</i>	<i>8-10% annually</i>
<i>lactic acid</i>	<i>27</i>	<i>25-30</i>	<i>4-9% annually</i>

Source: USDA-ERS, 1997; Sansavini & Verzoni, 1998

US is a net exporter of corn starch & starch derivatives. The major products (for food processing) in 1996 were: starch, glucose, glucose syrup (<20% fructose), pure fructose, glucose syrup (20-50% fructose), fructose syrups + solids, dextrans, and modified starches (US Department of Commerce, 1997). The most important volumes are exported to NAFTA members Canada & Mexico, Asia (Japan, Malaysia, Korea, Philippines, Indonesia, Taiwan,...), LAC, EU (UK, Netherlands,...), and Israel. 1997 US corn starches exports have increased by 8% over 1996.

The same source also lists US imports of cassava starch. In 1997, total import volume was 12,000 MT at an average value of US\$ 309/MT (most corn starches exported from the US are valued at US\$ 450-650/MT....). US cassava starch imported in 1997 originated mainly from Thailand (97%), but also included very small imported volumes from Brazil, Colombia, Costa Rica, Philippines and Ghana. Data for these latter countries cannot be accessed for individual country cassava starch exports.

R: Disaggregated data on starch utilisation shares (by type of starch) is required.

3. FUTURE PROSPECTS FOR CASSAVA UTILISATION

3.1 FOODS:

The previous sections have already included indications regarding future growth potential for several product groups. While traditional fresh root consumption in Colombia and Paraguay is subjected to negative effects of increasing urbanisation, decreasing cassava prices, relative to its principal substitutes, can boost per capita consumption, especially for the lowest income classes in urban areas. The same argument is valid for *farinha de mandioca* in North and Northeastern Brazil. Furthermore, regarding this latter product, quality improvement can also lead to increased consumption.

In Africa, evidence has been brought forth indicating that, a potential exists, for first, the development of traditional products that are cheaper and more efficient to produce (through improved processing), and secondly, the development of more convenient forms of traditional products targeting more urbanised consumers with according purchasing and food preferences.

Exported fresh cassava (mainly from Central America and to a lesser extent from West Africa) for EU and US markets shows additional but however, limited growth potential for "exotic foods" markets. Improved marketing efficiencies translating in lower prices, may boost future demand. Partial substitution of wheat by cassava flour for bakery & pastry industries has been succesful (in most cases) in several countries of the 3 cassava producing continents. However, most experiences are still at a semi-experimental level and/or have not been widely diffused. Nonetheless, increased future attention (including detailed market & feasibility studies) to this activity, especially in Africa constitutes an important development path.

3.2 FEEDS:

The "traditional" EU feed market is still cornered by Thai pellet exports. Although Thai pellet export profit margins have been under severe pressure, the exports will continue as long as CAP policies do not drastically change (*ceteris paribus*), since the pellet industry still has not yet written off long-term investments. The current Thai financial crisis may boost exports in the short term. Medium & long-term prospects are almost entirely dependant on world corn & soybean prices, EU domestic grain prices, and future EU policy changes. Continueing bullish starch demand in Thailand (and its export markets) will add additional pressure on Thai pelleters, in their competition for raw materials. A positive point is that increasing starch supplies, also increases (cheap) starch by-products that serve the pelleting industry as an additional raw material.

Some evidence from Africa indicates a growing potential for on-farm and off-farm cassava chips (+leaves) utilisation for animal feed. However, this seems to be very site specific and hence, this needs to be studied case by case (region by region). West-African cassava chip export potential (to EU) in the short-run is limited by the EU quota of 145,000 MT (at the low 6% tariff). Exports above this quota are prohibitive because of the high tariff. Cassava for feed utilisation has foremost a potential domestically rather than for export!

Future diffusion and/or intensification of cassava chipping & drying in LAC (beyond the current regions), depends largely on the ability of cassava chippers to further integrate with the private sector (with help of government and resarch support). In addition, national & international coarse grain prices, coupled to government interventions play an important role. The potential market exists, but the organization and integration of producers, processors, marketers and consumers need to be significantly improved.

On-farm utilisation of dried cassava chips (or flour) in Vietnam and China to supply expanding urban porc demand will continue to increase (especially in non-starch industry areas), but in the longer term, an increasing number of pigs will be fattened in specialized large-scale units (that may or may not be partially fed on cassava), reducing the profit margins for isolated and small household pig producers. This issue (to be analyzed in detail) is currently included in a regional integrated root & tuber project proposal, submitted to IFAD.

3.3 STARCHES:

Previous sections have left a clear impression that increasing and strong starch demand is driving the industry to novel partnerships, source materials and partners. While it seems that Asia is the current « hotspot » for both supply (cheap factors of production) and demand (bullish economic development), LAC is increasingly showing a profitable market as well. Future lowering of import regulation levels in high starch demand countries especially in Asia (and EU?) may further boost demand for cassava starches. It is however, dependant on cassava starch industry's technology adopters to successfully compete with potato and corn starches in the emerging markets (especially requiring modified & hydrolised starches). It will be necessary however, to first identify which will be the most appropriate starch market segments for subsequent targeting.

Africa seems to have various potentials market for cassava starches. The small starch volumes that are currently consumed, are largely imported (from US and EU). Although these volumes are small, the EU and US multinationals keep a very firm grip on their markets (monopolistic)! Furthermore, near future cassava market expansion, will be undoubtedly satisfied by the multinationals. Current local interest for cassava starch manufacturing seems mostly limited to relatively small-sized cases. However, the interest is growing in almost all major cassava producing countries, as local investors observe growing starch demand on the one hand, and cheap starch source crops on the other hand. However, while on paper, it may be relatively easy to demonstrate that cassava starch production is feasible in many countries of Africa, significant technical, financial, institutional and organizational constraints need to be overcome. Nonetheless, the opportunities seem to be present. Significant further technical, sector & starch market analyses are required in Africa to validate this theoretical local supply potential. An in-depth analysis regarding appropriate scale of starch processing units, seems also most needed

4. ISSUES & RECOMMENDATIONS FOR FURTHER STUDY

As in the previous sections already specific (by country/continent and domain/industry) recommendations have been made regarding further study needs, in this section, the authors will attempt to pull together the individual recommendations for each continent and/or country (since Phase 2 study activities are planned in this manner).

US & Canada:

1. Disaggregated price, production and export data-series, by type of starch and utilising industry. This will be crucial to assess future growth rates and relative potential. US Industry Census data seems to be one of the possible data sources.

EU + other European countries:

2. Disaggregated price, production and export data-series, by type of starch and utilising industry. A 1997 confidential report from the A.A.C. in Bruxelles on the European starch industry may be a starting point (if available???). Assessment of ex-Iron country markets is needed. Selected industry visits are essential.

3. Further insight in the "fresh" cassava imports may be useful, in order to assess and quantify future import growth (from African versus Latin exporters). Targeted interviews with selected importers in France and the UK (+ Germany?) will be necessary.

4. EU policies have significant effects on current & future cassava product trade. Further insights regarding expected policy changes and subsequent ex-ante impact analysis, seems necessary. This implies further study of policy regulations and a visit to pertinent European Commission officers in Bruxelles.

Asian cassava importing countries (Japan, Taiwan, Hong Kong, Korea, ...)

5. Recent domestic feed and starch market data is required (by utilising industry), in addition to current policies and expected policy changes, in order to assess import growth potential. Especially, Japan, merits attention.

Asian cassava import/export countries (Thailand, Vietnam, China, Indonesia, Philippines,)

6. Updated data-series need to be gathered and analyzed regarding domestic (i) on-farm and off-farm cassava chip supplies, costs and prices; (ii) root production costs and farm-gate prices; (iii) quantity of starch types, costs, factory-gate prices and by-product utilisation and value; (iv) starch utilisation industry shares and growth rates; and (v) direct and indirect cassava sector policies. Visits to selected cassava producers/flour/starch association managers, seems a first step. Cassava export association visits will be necessary for insights regarding expected future export assessments.

7. An assessment of the current and expected future impact from the on-going Asian financial and economic crisis vis-à-vis cassava sector developments, seems crucial.

Latin America & the Caribbean:

8. Complementary and updated information for Colombia, Paraguay and Venezuela is required regarding (i) on-farm and off-farm cassava chip supplies, costs and prices; (ii) root production costs and farm-gate prices; (iii) quantity of starch types, costs, factory-gate prices and by-product utilisation and value; (iv) starch utilisation industry shares and growth rates; and (v) direct and indirect cassava sector policies.

9. Brazilian starch information needs to be validated and more quantitative information is required regarding future domestic starch growth markets.

10. Future potential of partial wheat substitution by cassava flour will need site-specific studies that may be more pertinent for inclusion in integrated cassava project proposals. This is also recommended for higher quality traditional cassava products i.e. fresh cassava (*in bolsa*) in Colombia and Paraguay, *farinha de mandioca* (Brazil), and pre-cooked & frozen packaged cassava (all countries).

11. Fresh cassava exporters from Central America (Costa Rica) could be contacted to help assess future growth and alternative product portfolio possibilities.

Africa:

12. Regarding the potential for on and off-farm (national) cassava utilisation for animal feed detailed studies regarding supply and demand aspects need to be conducted on a one to one basis for each « potential » region. Some information for some (parts of) countries exist and are being used, but much is lacking. For many regions, a qualitative potential exists, but quantitative data needs to validate this. This regards on-farm and off-farm, and regarding the appropriate scale. A review of on-going experiences across projects (and countries) seems most useful.

13. Virtually the same recommendation can be made regarding the potentials for improved processed traditional products, products with partial wheat substitution, and cassava starch based products. More quantitative data needs to be collected (site-specific) and policies analyzed. A first step may be to critically evaluate on-going projects across regions.

14. Regarding most recommendations made, it does not suffice to just collect & analyze more data, but to make it more and easier accessible, and to provide a mechanism for updating this valuable information.

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ANNEXE A

Table A1. Distribution of cassava products using the categories provided in Table 1 and Figure 1.

Product Group/ Product Type	No. of alternative names	Country	No of villages where ranked 1st 2nd 3rd*	Total no villages (% of surveyed in country)
1. Fresh Roots				108
Ererebe group	6	Nigeria	0 1 10	11 (18%)
Foutou/fufu	2	Cote D'Ivoire	16 9 6+1	32 (80%)
	1	Ghana	10 3 2	15 (50%)
Tuber	12	Uganda	29 2 0	31 (97%)
Otherl		Various		19
2. Roasted Granules				78
Gari	2	Cote D'Ivoire	1 2 4+1	8 (20%)
		Ghana	7 13 2	22 (73%)
		Nigeria	25 22 1	48 (79%)
3. Steamed Granules				35
Attieke	1	Cote D'Ivoire	15 12 7	34 (85%)
Othersl	1	Ghana		1
4. Dried flours/pieces				267
<u>Acid soaked</u>				
Alebo	6	Nigeria	21 1 3	25 (40%)
Cossette	1	Zaire	15 16 0	33 (92%)
Fufu	2	Zaire	7 12 7+4	30 (83%)
Lafun	1	Nigeria	2 6 4	12 (20%)
Others	3	Nigeria		6
<u>Air dried</u> *				
Alebo	5	Nigeria	10 1 2	13 (20%)
Kabalagala	2	Uganda	0 7 4	11 (34%)
Kokonte	2	Ghana	9 8 11	28 (93%)
		Cote D'Ivoire	3 8 5+2	18 (45%)
Cassava flour (Tz)	12	Tanzania	6 10 5+7	28 (93%)
Cassava Flour (Ug)	5	Uganda	0 14 7	21 (66%)
Composite flour	5	Uganda	1 5 2	8 (25%)
Others	2	Various		5
<u>Mould fermented</u>				
Tanzanian	1	Tanzania	12 5 3+8	28 (93%)
Others	1	Uganda		1
5. Fermented pastes				47
<u>Grated roots</u>				
Agbelima	2	Ghana	3 3 3+1	10 (33%)
Placali	2	Cote D'Ivoire	4 8 11	23 (58%)
<u>Soaked roots</u>				
Akpu (fufu)	6	Nigeria	8 13 19	40 (63%)
Chikwangue	3	Zaire	12 2 5+5	24 (64%)
6. Products from leaves				
Total	5	Zaire, Ug, Tz		7
7. Drinks				
Total	14	Zaire, Uganda		22
8. Sedimented starches				
Starch	1	Nigeria	0 2 2+1	5 (8%)
9. Unclassified				
Total	5			5

* The number after the number of villages ranking the product third is the number of villages where the ranking was not recorded.

Table A2. EU Wheat starch exports to African countries

	1993		1994		1995		1996	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
	Tonnes	'000 US\$	Tonnes	'000 US\$	Tonnes	'000 US\$	Tonnes	'000 US\$
Morocco	118	31.9	107.7	18.3	6.2	4.8	7	3.1
Algeria	0	0.0	0	0.0	0	0.0	4.8	2.0
Tunisia	8.4	4.5	9.6	4.8	12	7.3	14.4	8.9
Egypt	16.8	5.5	16.2	19.3	6.7	7.5	18.8	16.1
Senegal	5.5	5.1	3.9	3.6	10.1	8.7	7.9	7.0
Ivory Coast	6.4	6.0	12.2	12.2	7.2	5.3	13.1	6.5
Benin	1	1.5	0	0.0	0	0.0	2.6	3.2
Cameroon	0	0.0	2.6	11.1	3.2	13.6	2	2.0
Zaire	0	0.0	13.7	4.7	8.3	3.5	5.2	2.0
Kenya	0	0.0	0	0.0	13.5	5.5	24.1	9.2
Madagascar	0	0.0	0	0.0	0	0.0	7.3	3.3
Reunion	0	0.0	0	0.0	0	0.0	2.8	2.9
Total	156.1	54.5	165.9	74.0	67.2	56.0	110	66.0

Source: DG VI, Eurostat

Table A3. EU potato starch exports to African countries.

	1993		1994		1995		1996	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
	Tonnes	'000 US\$	Tonnes	'000 US\$	Tonnes	'000 US\$	Tonnes	'000 US\$
Morocco	45.4	12.6	0	0.0	142.2	79.4	584.5	345.9
Algeria	1280	362.1	6	2.3	360.4	196.9	136.8	77.7
Tunisia	16.5	5.1	0	0.0	17.4	9.0	19.5	15.1
Libya	0	0.0	0	0.0	2.7	7.5	0	0.0
Egypt	0	0.0	121	72.0	101	51.0	100	82.6
Cape Verde	1.3	2.7	2.8	5.7	1	2.3	2	3.4
Guinea Biss.	0.6	0.7	0.1	0.5	0	0.1	0.1	0.5
Ghana	6	3.6	0	0.0	15.3	10.2	20	8.6
Nigeria	0	0.0	4.9	10.0	1	1.6	18.5	12.4
Angola	0.4	1.1	5.4	8.6	0.9	2.5	8	25.8
Reunion	0	0.0	0	0.0	23.8	48.3	6.6	14.3
Zambia	0	0.0	0	0.0	1.5	1.4	0	0.0
Zimbabwe	82.5	22.0	29.6	12.5	105	47.1	63	35.7
Lesotho	0	0.0	0	0.0	2	6.2	0	0.0
Total	1432.7	409.8	169.8	111.6	774.2	463.3	959	622.0

Source: DG VI, Eurostat

Table A4. Imports of Fresh Cassava to the EU by Country of Origin

Definition: Fresh and whole or without skin and frozen manioc, whether or not sliced, for human consumption.

	1993*		1994*		1995**		1996**		1997***	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
	Tonnes	'000 US\$	Tonnes	'000 US\$	Tonnes	'000 US\$	Tonnes	'000 US\$	Tonnes	'000 US\$
EU Total	3 409	1 914	3 480	2 509	4 022	3 015	5 001	3 571	4 147	3 187
Costa Rica	2 502	1 532	2 747	2 015	3 485	2 590	4 089	2 807	3 658	2 699
Ecuador	0	0	5	3	76	50	219	161	230	219
Surinam	133	68	411	213	188	133	272	205	26	18
Ghana	91	45	124	63	89	75	220	210	152	134
Malaysia	8	7	7	6	17	16	34	27	36	31
Barbados	0	0	0	0	17	13	22	15	1	1
Brazil	20	12	0	0	0	0	34	41	5	5
St Vincent	4	3	49	62	29	30	4	5	6	6
Dominican R.	0	0	8	2	28	10	10	8	0	0
Vietnam	2	3	10	10	7	7	22	16	7	17
Philippines	0	0	0	1	10	12	8	10	11	14
Honduras	131	86	63	45	20	18	0	0	0	0
Singapore	11	9	6	5	14	13	2	7	0	0
Nigeria	0	0	0	0	1	2	16	13	0	0
Ivory Coast	7	7	0	0	14	9	0	0	2	29
India	0	0	2	4	0	0	15	7	0	0
Guatemala	0	0	0	0	0	0	10	10	3	2
Indonesia ₄	15	32	35	67	9	21	2	5	0	0
Trinidad, Tob	0	0	0	0	0	0	11	13	0	0
Togo	0	0	0	0	10	7	0	0	0	0
El Salvador	0	0	0	0	0	0	0	0	9	7
Guyana	0	0	0	0	0	0	8	5	0	0
Grenada	0	0	4	4	7	6	0	0	0	0
Thailand	424	63	6	6	0	0	3	4	1	2
Jamaica	0	0	0	0	3	2	0	0	0	0
Congo	0	0	0	0	1	1	0	0	1	1
Cameroon	0	0	1	0	0	0	1	3	0	0
Zaire	0	0	0	0	0	1	1	1	0	0
Venezuela	32	23	0	0	0	0	0	0	0	0
USA	18	9	0	0	0	0	0	0	0	0
Dominica	9	10	0	0	0	0	0	0	0	0
Hong Kong	0	0	2	3	0	0	0	0	0	0
St Lucia	1	3	0	0	0	0	0	0	0	0

Notes:

* =

EU12

** = EU15

*** = EU15 preliminary figures

Sources:

DG VI and Eurostat.

**Table A5. Imports of Fresh Cassava to the US
by
Country of
Origin**

	'1996		1997*	
	Quantit y	Value	Quantit y	Value
	Tonnes	'000 US\$	Tonnes	'000 US\$
US Total	32 343	16 070	34 285	21 044
Colombia	39	18	0	0
Costa Rica	31 744	15 691	32 953	20 317
Dominican R.	78	26	170	142
Ecuador	31	11	221	118
Egypt	4	10	4	12
Fiji	0	0	2	12
Ghana	64	24	52	16
Honduras	21	7	26	14
Hong Kong	0	1	8	4
India	0	0	2	1
Indonesia	20	44	0	0
Ivory Coast	0	0	0	2
Jamaica	0	3	19	25
Malaysia	5	4	0	0
Mexico	66	0	154	31
Nicaragua	0	0	4	4
Nigeria	18	19	0	0
Panama	0	0	102	35
Peru	9	8	0	0
Philippines	198	188	201	199
Thailand	3	4	0	0
Tonga	40	11	12	13
Venezuala	0	0	344	94
Vietnam	3	1	12	4

Notes: * = Estimated values
Source: US Department of Commerce
web site

ANNEXE B

Supplementary internet web-sites bibliography¹⁶ on cassava, related & derived product utilisation, markets & trade (especially starches & derivatives):

<http://www.undp.org/>
<http://www.rockfound.org/>
<http://www.macfdn.org/>
<http://www.bellonet.org/>
<http://www.info.usaid.gov/>
<http://www.ntis.gov/data.htm>
<http://www.ifis.co.uk/online.html>
<http://www.mda.state.mn.us/docs/agdev/biotech/interbio.htm>
<http://www.fst.ag.ohio-state.edu/People/MANGINO/Curriculum/Syllabi/630-01.html>
<http://www.cato.com/biotech/>
<http://www.centers.agri.umn.edu/misa/site1.html>
<http://www.orst.edu/food-resource/references/carbohydrate/starch.html>
<http://www.nal.usda.gov/>
<http://www.ars.usda.gov/>
<http://www.nal.usda.gov/bic/>
<http://www.ntis.gov/>
<http://europa.eu.int/cj/en/index.htm>
<http://www.census.gov/>
<http://www.nal.usda.gov/bic/www.html>
<http://www.oecd.org/ehs/service.htm>
<http://www.reeusda.gov/nri/abstract95/food.htm>
<http://www.fedworld.gov/cgi-bin/waisgate>
<http://www.info.usaid.gov/resources/>
<http://www.info.usaid.gov/cgi-bin/wwwwais>
<http://www.info.usaid.gov/enric/index.html>
<http://www.scripps.edu/>
<http://www.peg.apc.org/~aushs/intsites.htm>
<http://www.nbiap.vt.edu/>
<http://www.reeusda.gov/>
<http://www.nbiap.vt.edu/isb-marks.html>
<http://www.itc.org/>
<http://www.wto.org/>
<http://www.agritrade.org/>
<http://tradeport.org/>
<http://ciber.bus.msu.edu/busres/statinfo.htm>
<http://www.europages.com/business-info-en.html>
<http://www.ntu.edu.sg/library/statdata.htm>
<http://www.wri.org/wri/wr-96-97/>
<http://www.worldbank.org/>
<http://www.fao.org/>
<http://www.ilo.org/>
<http://www.worldbank.org/html/extldr/backgrd/ibrd/ibrd.htm>
<http://www.imf.org/>

¹⁶ Collected by the authors and by courtesy of Dr. David Verzoni, University of Bologna, Bologna, Italy

<http://www.usitc.gov/tr/GOVERNMENT8.HTM>
<http://lib-www.ucr.edu/infomine/finding.html>
<http://lib-www.ucr.edu/govpub/>
<http://www.usitc.gov/tr/NEWSGRO7.HTM>
<http://www.usitc.gov/tr/INDUSTR2.HTM>
<http://www.ift.org/meet/techprog.html>
<http://www.ifc.org/PUBLICAT/PRESS/DATE/1993/PAAGRIBU.HTM>
<http://www.scisoc.org/aacc/pubs/journ/cc/cctc.htm>
http://www4.linknet.net/S_POTATO/Index.htm
<http://www.csi.ad.jp/ABOMB/>
<http://www.odci.gov/cia/publications/nsolo/>
<http://www.agriculture.com/worldwide/partners/agonline.html>
<http://www.xc.org/echo/bdcompc7.htm>
<http://www.hort.purdue.edu/newcrop/crops/cropfactsheets/apios.html>
<http://www.cato.org/pubs/pas/pa-241.html>
<http://www.frontierherb.com/spices/notes/spices.notes.no2.html>
<http://www.faseb.org/biophys/society/biohome.htm>
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<http://www.ciat.cgiar.org/espanol/biblioteca/yuca1.htm>
<http://www.ciat.cgiar.org/comunic/news7.html>
<http://web.icppgr.fao.org/CPGR/3-96/3NDA.html>
<http://ci.mond.org/home.html>
<http://www2.bonet.co.id/cip/index.html>
<http://ffas.usda.gov/commodity.html>
<http://www.xc.org/echo/echohpon.htm>
<http://www.xc.org/echo/>
<http://www.fao.org/waicent/faoinfo/economic/economic.htm>
<http://web.icppgr.fao.org/>
<http://www.fao.org/WAICENT/FAOINFO/ECONOMIC/giews/english/fo/fo9706/fo9706.htm>
<http://www.fao.org/WAICENT/FAOINFO/ECONOMIC/giews/english/fo/fo9706/httoc.htm>
<http://apps.fao.org/cgi-bin/nph-db.pl?subset=agriculture>
<http://hammock.ifas.ufl.edu/>
<http://www.fao.org/waicent/faoinfo/economic/giews/english/fo/fo9604/fo9604w2.htm>
http://www.tuns.ca/foodsci/foodsci_search.html
<http://www.corn.org/web/foodseed.htm>
<http://www.orst.edu/food-resource/information/starch.html>
<http://www.freetel.com/>
<http://www.foodexplorer.com/product/apps/history/FF01722.HTM>
<http://ci.mond.org/9705/970516.html>
<http://fadr.msu.ru/rodale/agsieve/txt/vol2/7/art5.html>
http://indis.msu.ru/rice/echo_cordis/cordn2110.html
<http://jiio6.jic.bbsrc.ac.uk/abstracts/14ses.html>
http://mann77.mannlib.cornell.edu/reports/erssor/specialty/ius-bb/industrial_uses_of_agricultural_materials_08.06.97
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<http://wjh-www.harvard.edu/soc-sci/rel/govt.html>
<http://www.bib.wau.nl/agralin/ss-agric.html>
<http://www.biol.tsukuba.ac.jp/~macer/TTEC/TTECHS.html>
<http://www.fao.org/waicent/faoinfo/economic/faodef/fdef02e.htm#top>
<http://www.milcom.com/>
<http://www.sti.nasa.gov/thesaurus/C/word2115.html>
<http://www.undp.org/tcdc/ins3018.htm>
<http://www.unsystem.org/index7.html>
<http://www.usda.gov/oce/waob/wasde/latest>
<http://www.easynet.co.uk/ifst/resource.htm>
<http://www.undp.org/tcdc/inres.htm>
<http://www.easynet.co.uk/ifst/federal.htm>
<http://www.bf.rmit.edu.au/~wen/intrade.html>
<http://www.agribiz.com/agInfo/aglinks.html>
<http://www.agric.gov.ab.ca/food/invop/invop30.html>
<http://atlantech.atlantech.fr:8080/RESEARCH/TOPICS/F9/f91.html>
<http://www.grains.org/world/asia/japanbio.htm/>
<http://www.york.ac.uk/org/macromol/docs/new.htm>
<http://www.foodstarch.com/index.html>
<http://www.ncaur.usda.gov/>
<http://www.hort.purdue.edu/newcrop/default.html>
<http://www.spg.wau.nl/pv/>
<http://www.zestec.nl/crf/starch/poster.html>
<http://www.milcom.com/fintrac/mps/postsweet.html>
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<http://foodsci.unl.edu/OLED/foodchem/properti.htm>
http://www4.linknet.net/s_potato/refs_mr.htm
<http://www.spg.wau.nl/pv/theme2.htm>
<http://www.scicentral.com/B-0foods.html>
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<http://www.corn.org/web/shipprod.htm>
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<http://ifs.plants.ox.ac.uk/ifs/itfn/nri.htm>
<http://www.xc.org/echo/tnswtpot.htm>
<http://www.grains.org/>
<http://www.grains.org/>
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