The impact of mechanization in smallholder rice production in Nigeria

Promising business cases for rice smallholders for income increasing and climate smart interventions

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Olam

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Background

Company : Olam

Region case study: Nigeria

Rice Farmers Olam: 66,000 (of which ≈ 50% in Nigeria)

Product : Rice

Aim: Food loss reduction, increase farmer profit, decrease greenhouse gas emissions (GHGe)

Rice loss reduction pilot Nigeria: intervention analysis in rice harvesting, threshing (and winnowing)

Goal: analyse the impact on food loss and farmer profit and greenhouse gas emissions

1. when switching from manual to mechanised rice harvesting
2. when switching from manual to mechanised rice threshing

Pilot set up: Harvest

- 5 farmers were selected
- each farmer marked 6 pieces of land of 24m^2: 3 for manual harvesting and 3 for mechanised harvesting with a reaper
- weighing (using digital scale) of:
    - harvested material (plant material + paddy) (before drying)
    - paddy left on soil on harvested piece of land
    - harvested material (plant material + paddy) (after drying)
    - mechanically threshed paddy
- moisture content measurement of paddy before and after drying

Pilot set up: Threshing (and winnowing)

- same 5 farmers were selected
- each farmer marked 6 pieces of land of 24m^2 for manual harvesting
- 3 harvested volumes were manually threshed as usual and the other 3 were mechanically threshed
- weighing (using digital scale) of:
  - harvested material (plant material + paddy) (after drying)
  - mechanically threshed paddy
- winnowing was included (integrated in mechanised threshing) and assumed to have no significant loss (according to Olam experts)

Some pictures from the pilot from manual practices to mechanization

Manual | **Mechanized**

Figure H.B. Axmann 2021, photos Olam International

Results (reduction food loss)

Harvest pilot:

- *manual harvesting*: 9.6% loss of available paddy on land
- *mechanized harvesting*: 0.9% loss of available paddy

The main reason for the huge difference in loss is the fact that the reaper takes everything from the land, whereas with manual threshing some material is not taken from the land. The lost paddy on the soil is less relevant

Results (reduction food loss)

Threshing pilot:

- *manual threshing*: 31.1% of the weight of the dried input plant material (incl. paddy) was threshed as paddy
- *mechanized threshing*: 33.1%

The difference in loss for the 2 threshing scenarios can be calculated and equals 180 kg per ha.

Absolute values for threshing losses can be derived via a work-around:

- *mechanized threshing*: 1% loss assumed based on literature (Alizadeh, M. R., & Allameh, A. (2013). Evaluating rice losses in various harvesting practices. *International Research Journal of Apllied and Basic Sciences*, *4*(4), 894–901. http://www.irjabs.com/files_site/paperlist/r_767_130422105800.pdf; Hodges, R. J., Buzby, J. C., & Bennett, B. (2011). Postharvest losses and waste in developed and less developed countries: opportunities to improve resource use. *The Journal of Agricultural Science*, *149*(S1), 37–45. internal-pdf://252.165.214.139/postharvest_losses_and_waste_in_developed_and_.pdf; Nath, B., Hossen, M., Islam, A., Huda, M., Paul, S., & Rahman, M. (2016). Postharvest Loss Assessment of Rice at Selected Areas of Gazipur District. *Bangladesh Rice Journal*, *20*(1), 23–32. https://doi.org/10.3329/brj.v20i1.30626; Selvi, R., Kalpana, R., & Rajendran, P. (2002). Pre and post harvest technologies to reduce yield losses in rice – A review. Agricultural Reviews, 23(4), 252–261.)
- *manual threshing* 7% loss (based on the differences in yield).

Results (profit & GHGe reduction) Scenario 1: mechanised harvesting

- Olam farmer has 1.92 ha average (pilot 2019)
- Average farm price is 169 Naira/kg = 0.37 USD/kg (400 Naira ~ 1 US $)

Results per harvest of switching to **mechanised harvesting**:

Scenario 1: Mechanised harvesting			
Harvest impact/harvest	Harvesting loss reduction*	Profit increase** US$***	GHGe reduction
Per ha	299 kg	126	1,042 kg
Per farmer	575 kg	243	2,000 kg
Olam (32,800 farmers Nigeria)	18.8 kton	7,961K	65.6 kton
All rice farmers Nigeria****	958 kton	405M	3.3 Mton

* = of paddy, directly after harvest, before drying
** = after mechanized threshing
*** = 1 US $ ~ 400 Nigerian Naira
**** = 1.43 million, average farm size 2.24 ha (KPMG , Rice industry Review, 2019)

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Results (profit & GHGe reduction) Scenario 2: mechanised threshing

Results per harvest of switching to **mechanised threshing**:

Scenario 2: Mechanised threshing			
Threshing impact	Loss reduction (weight)	Profit increase US$	GHGe reduction
Per ha	180 kg	76	716 kg
Per farmer	346 kg	146	1,374 kg
Olam (32,800 farmers)	11.4 kton	4,789K	45.1 kton
All rice farmers Nigeria	577 kton	244M	2.3 Mton

Results (profit & GHGe reduction) Scenario 3: mechanised harvesting and mechanised threshing

Results per harvest of switching to **mechanised harvesting and mechanised threshing**

Scenario 3: mechanised harvesting and mechanised threshing			
Harvest impact	Loss reduction (weight)	Profit increase US$	GHGe reduction
Per ha	479 kg	202	1,696 kg
Per farmer	921 kg	389	3,256 kg
Olam (32,800 farmers)	30.2 kton	12,760K	106.8 kton
All rice farmers Nigeria	1,535 kton	648M	5.4 Mton

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Business case (1) - Assumptions

- Information provided by Olam staff
- Assume farmers rent the equipment

Parameter	Value
Labor costs (N per hour)	125
Rice price (N per kg paddy)	169
Fuel price (N per liter)	165.7
Harvesting labor needed (hours per ha)	160
Threshing labor needed (hours per ha)	80
Cost of renting reaper (model 4GL-120) (N per ha)	17,500
Cost of buying reaper (N)	820,000
Reaper fuel consumption (liters per ha)	4.5
Reaper capacity (ha per day)	1
Cost of renting thresher (model Sh 101-2) (N per ha)	10,000
Cost of buying thresher (N)	350,000
Thresher fuel consumption (liters per ha)	5.5
Thresher capacity (metric ton of input (dried plant material) per hour)	1

Business case (2) - Results

	Baseline	**Scenario 2**	**Scenario 3**
Harvesting	Manual	Manual	Mechanized
Threshing	Manual	Mechanized	Mechanized
Average yield (kg paddy per ha)	2,768	2,967	3,257
Revenue (N per ha, NN*)	470,823	501,423	550,433
Harvesting costs (N per ha, NN)	20,000	20,000	20,246
Threshing costs (N per ha, NN)	10,000	13,161	13,536
Revenue increase (N per ha, NN)		30,589	79,599
Cost increase (N per ha, NN)		3,161	3,782
Financial result (N per ha, NN)		**+ 27,428**	**+ 75,871**
Financial result (%)		**+ 5.8 %**	**+ 16.1 %**
Labor hours saved		62 in threshing	144 in harvesting, 59 in threshing

* NN= Nigerian Naira, 400 NN ~ 1 US$

- Positive business case for farmers to rent machinery
- Up-front costs may be prohibitive
- Purchasing equipment has even higher up-front cost, but is feasible through farmer cooperatives
- Improving access to financing can help overcome barriers

Equipment cost comparison between buying and renting reaper and thresher (for individual farmer in cooperative)

	1 harvest	2 harvests	3 harvests	4 harvests	5 harvests
Cost of renting (N per harvest per farmer, NN)	27,500	27,500	27,500	27,500	27,500
Cost of buying (N per harvest per farmer, NN)	78,000	29,000	26,000	19,500	15,600

- With a reaper costing ~ N820,000 (~US$ 2,050) to buy and a thresher ~N350,000 (~US$875) the upfront cost for a single farmer with 2 hectares in a 15-farmer cooperative would be ~N78,000
- Buying becomes the more cost-effective option if cost of buying with a cooperative of 15 farmers can be spread over 3 harvests or more

Summary scenario assessment of Greenhouse Gas emissions: baseline versus mechanization via ACE-calculator (Agro-Chain Greenhouse Gas emissions calculator) including Food loss induced Greenhouse Gas emissions and emissions from mechanization

	Baseline	**Scenario 1**	**Scenario 2**	**Scenario 3**
Total paddy rice growth (kg/ha)	3,315	3,315	3,315	3,315
Harvesting method	Manual	Mechanized	Manual	Mechanized
Losses in harvest	9.55%	0.93%	9.55%	0.93%
Threshing method	Manual	Manual	Mechanized	Mechanized
Losses in threshing	7%	7%	1%	1%
Total paddy threshed rice (kg/ha)	2,789	3,054	2,968	3,251
GHGe per kg produced paddy rice (kg CO_2-eq. per kg threshed rice) (assuming crop GHG emission factor 3.66kg CO_2-eq. per kg paddy	4,352	3,979	4,096	3,744
Climate impact of mechanization (emissions avoided, kg CO_2-eq)				
Per ha (kg CO_2-eq.)		1,042	716	1,696
Per farmer Olam (1.92ha) (kg CO_2-eq.)		2,000	1,374	3,256
Rice farms in Nigeria (1.43 million/2.24ha) (Mton CO_2-eq.)		3.3	2.29	5.4

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Results ACE-calculator Rice

ACE calculator
Agro Chain greenhouse gases Emissions

Jan Broeze
Wageningen Food & Biobased Research
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Case/scenario title:	Manual harvesting and threshing		Mechanized harvesting; manual threshing		Manual harvesting and mechanical threshi		Mechanized harvesting and threshing	
Marketed food product CLIMATE IMPACT	*4.352 kg CO_2-EQ. per kg sold on market*		*3.979 kg CO_2-EQ. per kg sold on market*		*4.096 kg CO_2-EQ. per kg sold on market*		*3.744 kg CO_2-EQ. per kg sold on market*	
FOOD LOSS (lost edible part)	*15.9%*		*7.9%*		*10.5%*		*1.9%*	
FOOD LOSS ASSOCIATED GHG EMISSIONS	*0.691 kg CO_2-EQ. per kg sold on market*		*0.313 kg CO_2-EQ. per kg sold on market*		*0.427 kg CO_2-EQ. per kg sold on market*		*0.072 kg CO_2-EQ. per kg sold on market*	
Crop GHG intensity factor:		3.661		3.661		3.661		3.661
Apply either typical loss factor and total on-farm post-harvest GHG inducing emissions:								
Select data set for on-field operations								
Moisture and residues loss		0.%		0.%		0.%		0.%
Food loss		15.88%		7.86%		10.45%		1.92%
Harvesting and postharvest on-field Fuel use (liter per kg product)		0.		0.		0.		0.
... or select specific operations (expand rows)	Include process for: 1. Harvest, 2. Field drying (optional, default 22 ->18% moisture), 3. Hauling 4. Threshing/winnowing							
	Specific operations, expand below rows if h		Specific operations, expand below rows if h		Specific operations, expand below rows if h		Specific operations, expand below rows if h	
Specific process 1:	harvesting: hand reaping, sic		harvesting: machine reaping		harvesting: hand reaping, sic		harvesting: machine reaping	
Moisture and residues loss		0.%		0.%		0.%		0.%
Food loss	9.55%	9.55%	0.93%	0.93%	9.55%	9.55%	0.93%	0.93%
Fuel use (liter per kg product)		0.	0.0015	0.0015		0.	0.0015	0.0015
Specific process 2:								
Moisture and residues loss		0.%		0.%		0.%		0.%
Food loss		0.%		0.%		0.%		0.%
Fuel use (liter per kg product)		0.		0.		0.		0.
Specific process 3:	collection, hauling: trolley [N		collection, hauling: trolley [N		collection, hauling: trolley [N		collection, hauling: trolley [N	
Moisture and residues loss		0.%		0.%		0.%		0.%
Food loss	0.%	0.%	0.%	0.%	0.%	0.%	0.%	0.%
Fuel use (liter per kg product)		0.		0.		0.		0.
Specific process 4:	threshing: manual [Nath et al		threshing: manual [Nath et al		threshing: axial flow, tractor-		threshing: axial flow, tractor-	
Moisture and residues loss		0.%		0.%		0.%		0.%
Food loss	7.%	7.%	7.%	7.%	1.%	1.%	1.%	1.%
Fuel use (liter per kg product)		0.		0.	0.002	0.002	0.002	0.002
Specific process 5:								
Moisture and residues loss		0.%		0.%		0.%		0.%
Food loss		0.%		0.%		0.%		0.%
Fuel use (liter per kg product)		0.		0.		0.		0.

Guidelines | ACE Calculator | Processes | ProcessesRice | GHGEFSubSaharanAfrica | LossFSubSaharanAfrica | GHGEFSouthSouthEastAsia | LossFS(...

Overall conclusions

- Introduction of machinery in threshing and harvesting in rice in Nigeria can:
  - reduce food losses and increase the amount of paddy yield per ha by **14 % ~ 479 kg of paddy**
  - provide a positive business case for smallholder farmers to improve their livelihood, net income increase of ~ 189 $ per ha/ Olam farmer ~ 389 $
  - save > 200 labour hours
  - significantly reduce the GHGe; 1,696 kg CO_2-eq per hectare avoided

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Overview results per harvest of switching to mechanized harvesting and/or threshing

	Scenario 1 Switching to mechanized harvesting		Scenario 2 Switching to mechanized threshing		Scenario 3 Switching to mechanized threshing and mechanized harvesting	
Impact	**Loss reduction (kg)**	**Profit increase Naira*/US$**	**Loss reduction (kg)**	**Profit increase Naira*/US$**	**Loss reduction (kg)**	**Profit increase Naira*/US$**
Per ha	299 kg	50,531/126	180 kg	30,420/76	479 kg	80,555/202
Per farmer Olam (1.92 ha)	575 kg	97,175/243	346 kg	58,406/146	921 kg	155,650/389
Farmers linked to Olam in Nigeria (32,800)	18.8 kton	3.2 bln/7,961K	11.4 kton	1.9 bln/4,798K	30.2 kton	5.1 bln/12,760K
All rice farmers Nigeria (1.43 million/2.24 ha)	958 kton	162 bln/405M	577 kton	97 bln/244M	1,535 kton	259 bln/648M

* 400 Naira ~ 1 US $

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The challenge

- Challenges to overcome investment costs ~ 2,925 $US for reaper & thresher:
    - ability of individual farmers to co-invest and cover the higher upfront cost of buying equipment
    - access to finance for farmers and service providers to invest in mechanization
    - the capacity of farmer cooperatives to procure, maintain and store the equipment

Sources of References

- Scientific article (currently under review) in Cleaner Engineering and Technology: 'Mechanization in rice farming reduces greenhouse gas emissions, food losses, and constitutes a positive business case for smallholder farmers – results from a controlled experiment in Nigeria' (Bob Castelein, Jan Broeze, Melanie Kok, Heike Axmann, Xuezhen Guo, Han Soethoudt)

Thank you
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