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Design of vegetable garden for income estimation toward to agro-sanitation business model, a case study in Burkina Faso

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Abstract:
For a sustainable adaptation of decentralized and resource recycling based sanitation system, giving a clear incentive for users and setting a suitable target cost of sanitary facilities are required. To maintain the incentive which is vegetable production cultivated with urine, compost and greywater in the case of rural area in Burkina Faso, sustainable agricultural technique should be also considered. In the present study, a model of adequate crop rotation was designed from question survey in rural area.

Available greywater in one family group was 80 – 185 L from 8-9 persons. Using the gray water, a size of newly-made tomato garden was estimated 20-46 m^2 for rainy season and 11-25 m^2 for dry season. A model of crop rotation was prioritized irrigation efficiency. The rotation was proposed as: one compartment was for vegetables for sell, second was sorghum because of its high draught stress and third was gumbo due to high demand of local people. If rural families cultivate the crop rotation model, 100-240 EURO was roughly estimated as maximum income, based on wholesale price in local market.

We concluded that design of crop rotation lead us rough income estimation for cost setting of sanitation facilities.

Keywords: *irrigation requirement, vegetable marketability, income estimation, field survey*

Introduction

Improved sanitation has become a global important issue, highlighted by the UN Millennium Development Goal (MDG) who target to 'halve by 2015 the proportion of people without access to basic sanitation'. However, one speculation has shown a difficulty of the MDG achievement in developing countries (WHO and UNICEF, 2010). In order to overcome the difficulty, decentralized and resource recycling based sanitation system such as Ecological Sanitation (Esrey, 1998) and On-site Wastewater Differentiable Treatment System (Lopez *et al*, 2002) has been proposed. Advantages of the decentralized system have been known well: low cost investment to install and maintain, no potable water usage and nutrient recycle (Winblad, 2004). The paradigm shift from centralized to decentralized sanitation system accompanies with change of operation and maintainance responsibility from organizations to individual users. For a sustainable use of the decentralized system, therefore, clear incentive for the individual users should be essential from the practical view. One of the clear incentive is direct income from sanitation by-products such as urine and feces (Grambauer, 2010) and agricultural products cultivated with the sanitation by-products (Fogelberg, 2010)

In Burkina Faso where is located in sub-Sahel region, the proportion of population using an improved sanitation facility was 33% in urban area and only 6% in rural area at the time of 2008 (WHO and UNICEF, 2010). The under-five mortality rate is 169 per 1000 live birth and diarrhea occupies 19% of cause of these deaths. Water and sanitation are urgent issues in the country. On the other hands, the country belongs to the semi-arid zone and the main soil type is Lixisols. It is possible to undertake agriculture but the productivity is low and fragile due to unstable rainy water, low-fertility soils and low opportunity to access to chemical fertilizer for small-scale famers. According to a feasibility study in the area (Ushijima, 2012), main income source of the rural people was vegetable production and the cultivation was conducted without adequate amount of chemical fertilizer and composts. Besides, the vegetable cultivation was conducted near small scale dam lake where is far from their house, because irrigation water limit the cultivation near house. Therefore, not only sanitation system but also agricultural technology in the area requires paradigm shift to increase their life of quality.

We are proposing the comprehensive agro-sanitation concept of resources recycling sanitary system linked to agriculture with composting toilet and simple gray water treatment facility such as slanted soil facility for rural area in Burkina Faso (Fig. 1). In the system, wastewater from a household is fractioned into feces, urine and gray water. Feces are aerobically decomposed by a composting toilet (Fig. 2A). Compost made by the toilet can be used as soil conditioner and supply phosphorus for vegetable (Hijikata, 2011a). Domestic gray water is converted to irrigation water by a slanted soil facility (Fig. 2B) (Ushijima, 2011a). Source separated urine is able to use as fertilizer (Müllegger, 2010). Using these three agricultural materials, vegetable is produced near users house to increase the excrete asset. Then, the productions are sold in local market. On the other hands, cost setting of these sanitation facilities should be discussed to adapt the comprehensive agro-sanitation system in the area.

For a sustainable vegetable production, furthermore, adequate crop rotation should be also designed to avoid injury by continuous cropping and soil debasing. Since the source-separated urine and greywater from household contained sodium which would inhibit vegetable growth (Pearson, 2008; Hijikata, 2011b), the recovery is also considered in the rotation. In the present study, therefore, a model of adequate crop rotation for comprehensive agro-sanitation system was designed in order to sustainable vegetable production and to estimate income for user's incentive and cost setting of the facilities, based on field survey information about vegetable marketability in local market, local agricultural techniques and available irrigation amount in rural families.

Methods

Field survey was conducted in Ouagadougou city and Ziniare city with translators.
Vegetable marketability and vegetable distribution network was questioned to both farmers and brokers.
Question survey for 3 families (DA concession, CE concession and IE concession), which already committed to install and use as a pilot model, was conducted to estimate available amount of sanitary products.
Irrigation requirement for vegetables cultivation was calculated by FAO method (FAO, 1986) with climate data of Ouagadougou station (FAO). Available amount of urine and compost was estimated by family number of the pilot-family. Based on the information, a size of vegetable garden area was estimated and crop rotation was designed as a model.

Results and Discussion

Distribution system from farmer to consumer

In a current situation, farmers have two routes to sale their vegetables. One is sale in local market and second is direct sale to a broker (Fig. 3). In the former case, the farmer transfers their vegetables to local market by bicycle or donkey cart. Then, the vegetables are sold to broker, who comes from capital city, with negotiation. Some of vegetables are sold to retailers in the local market through the broker. But the vegetable quality seemed to be worse than that of others. The others are transferred to wholesale market in capital city by the broker with bus. Te vegetables are repacked to small unit to sale for retailer in capital city. Retailer comes to the wholesale market and buys in the vegetables. In the later case, individual broker directly comes in farm land and buys in farmers vegetables at the place. We couldn't identify the sold place in that case.

Sale price from farmer to broker

The sale price from farmer to broker, which is income for farmer in other words, was questioned to broker in local market in Ziniare and farmer in Ouagadougou in different season. The higher marketability products were tomato, onion and qurgete (Table 1). Carrot and cabbage were also traded at relatively higher price around capital city. Most of vegetables are sold as a unit base using 50 kg soil bags which volume is about 40 L. In the tomato case, wood box are normaly used as a sold unit and small basket is also used in local market. In the case of carrot and cabbage around capital city, broker comes to farmers land and buys in the products as a cultivation area or piece. But we were seldom to see these two vegetables in Ziniare market.

According to a seed company in capital city, tomato and onion are exported to neighbor countries, where are Ghna, niger, togo, cort diboal. Therefore, the capacity of needs for tomato and onion would be larger. Furthermore, onion, chili pepper and gumbo are preferable for small state famer, because refrigeration technology is not diffused in this area but these products are able to storage by natural drying. From the view of marketability and storage, tomato, onion, cabbage, carrot, chili pepper and gumbo are selected as a candidate vegetable production as an income source of agro-sanitation system.

Water usage and potential amount of irrigation

Ushijima (2012) has been reported that agricultural production was limited by irrigation amount in the area. Furthermore, greywater from household are able to be used as irrigation, when a simple slant soil treatment system was introduced (Ushijima, 2011a). Therefore, assumed bathing used water and laundry used water as an irrigation source, potential amount of irrigation was estimated in three pilot-families from the question survey (Table 2).

The result showed that total water usage in the pilot-families was 1120, 160 and 200 L/day/concession and the mean value of the usage per capita was 28.3 L/day/capita. Potential amount of irrigation in the pilot-family was estimated to 391, 85 and 185 L, respectively.

Climate and irrigation requirement

ET_0 and effective precipitation (P_e) was calculated with Ouagadougou climate data (Table 3). High ET_0 value and low P_e value was observed from Feb to May. Low ET_0 value and high Pe value was observed from Jun to Sep.

Using these climate data (Table 3), growth stage based crop factor (K_c) (Table 4) and growth stage period (Table 5), maximum irrigation requirement during cultivation period was calculated (Table 6). The result showed that high amount of irrigation was required when the vegetables cultivation was started from Dec, Jan and Feb. In the period, the irrigation requirement was approximately reached 5.9 – 7.4 mm/m^2/day. On the other hands, carrot and cucumber cultivation requested lower amount of irrigation than other vegetables. This indicated that it is better to choice carrot and cucumber for the dry season cultivation from the view of irrigation efficiency.

Design of crop rotation

For a sustainable agricultural productivity and stable income, design of crop rotation is required. One crop rotation model was designed, considered with vegetable marketability, irrigation requirement, general crop rotation rule and local crop cultivation style (Fig. 4). In the model, three rotations garden was proposed; one rotation was vegetables for sell, second was sorghum because of its moderate draught tolerance and third was gumbo due to high demand of local people. In the vegetables rotation, better rotation was proposed as tomato or chili pepper from Apr to Aug, onion from Aug to Des and cucumber, courgette or carrot from Jan to Mar as a low irrigation vegetable. All sanitary products, which are treated greywater, urine and compost, are applied in the vegetable rotation, since the rotation is expected as main income source. In the sorghum cultivation as a second rotation, it is assumed that sorghum is cultivated by local technique with rain-fed and no-sanitary products. During the cultivation, it is expected that accumulated sodium in soil is removed to sorghum shoot and leached with rain (Qadir, 2005). In gumbo cultivation as a third rotation, it was assumed that gumbo was cultivated by local agricultural technique with rain-fed, urine and compost. The gumbo has been cultivated as self- consumption in pilot-families, but also it was sold in local market. Therefore, the gumbo is expected as both self consumption and income source.

Estimation of available cultivation area

From the results of potential irrigation, irrigation requirement and crop rotation, available cultivation area in each pilot-family was estimated (Table 7). The area in DA concession with 23 persons was estimated as larger and it was 100 m^2 in Apr start and 50 m^2 in Jan start. The area in CE concession with 8 persons was estimated as smaller and it was 20 m^2 in Apr start and 10 m^2 in Jan start.

Income estimation

Income estimation was calculated from vegetable marketability and target yield. The vegetable yield is affected by soil and climate in sub-sahel region. Therefore, the decrease factor was considered as 20% in the estimation. Considered to filling rate and mean value of wholesale price (farmer to broker), rough income was estimated. The estimation showed that Tomato, onion, courgette and carrot was well income source (Table 8).

Considered to the income estimation and available vegetable area in pilot-family, maximum income, which is sum of tomato, onion, courgette and gumbo, in the pilot-family was also estimated (Table 9). the maximum income estimation showed that GE concession potentially have 337,000 FCFA (518 EURO) income from 23 persons' waste water. GE concession is constructed 23 persons and 3 family groups. Thus, the maximum income in one family group was estimated to 170 EURO. Besides, CE and IE concession have 69,000 FCFA (106 EURO) and 160,000FCFA (246 EURO). Therefore, composting toilet and shower room with greywater treatment system and urine collection system potentially gives families 100-240 EURO as a maximum gain.

On the other hands, the cost of composting toilet itself (include only materials cost) were reported 100 EURO for sitting type of composttoilet itself (Ushijima, 2011b). Therefore, financial support to install the toilet would be essential. Besides, technical development to reduce the cost also further required.

Conclusions

In the present study, one model of crop rotation design using sanitary by-products was proposed to estimate potential income in rural family, based on information about local climate and local market. The estimated rough income let us know a cost setting for sanitary facilities. The present study implied that 100-240 EURO was expected as maximum income in pilot-families. This value may become one target of technical cost setting to develop composting toilet and greywater treatment systems. Considered to the sub-Sahel region, irrigation water strongly limits agricultural productivities. Therefore, greywater treatment system contributes to expand available vegetable garden area and its productivity. This rises a composting toilet value.

Acknowledgment

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Figure legends

Table 1 vegetable price from farmer to broker in market

	FCFA	unit	volume	survey place
Tomato	3000	small basket		Ziniare
	3500	middle basket		Ziniare
	5000	large basket		Ziniare
	15000-20000	tomato box	200L	Ziniare
Onion	7500-10,000	50kg bag	40L	Ziniare
Gumbo	4000	50kg bag	40L	Ziniare
Egg plant	2500-4000	50 kg bag	40L	Ziniare
chili pepper	5000-6000	50 kg bag	40L	Ziniare
sweet pepper	3000	50 kg bag	40L	Ziniare
courgette	7000-12500	50 kg bag	40L	Ziniare
carrot	10000	10 m2		Ouagadougou
cabbage	50-100	1 number		Ouagadougou

Table 2 Question survey results about water usage and potential amount of irrigation in three pilot-families.

	Persons	Total water use (L)	Bathing (L)	Laundry (L)	Irrigation potential (L)
DA consession	24	1120	336-672	36	391-707
CE consession	8	160	72	13	85
IE consesion	11	200	165	20	185

Table 3 ET_0 and Pe in Ouagadougou climate

month	ET_0 mm/day	Pe mm/month
Jan	5.9	0
Feb	6.6	0
Mar	7.3	0
Apr	7.5	4.4
May	6.8	33.6
Jun	5.6	62.4
Jul	4.2	120
Aug	4	157.6
Sep	4.4	86.4
Oct	5.3	8.6
Nov	5.4	0
Dec	5.2	0

Table 4 Crop factors of four growth stage in several vegetables.

	Crop factor (Kc)			
Crop	initial stage	development stage	Mid season stage	late season stage
Tomato	0.45	0.75	1.15	0.8
Onion	0.5	0.75	1.05	0.85
Chili pepper	0.35	0.7	1.05	0.9
Cucumber	0.45	0.75	0.9	0.75
Gumbo	-	-	-	-
Cabbage	0.45	0.75	1.05	0.9
Carrot	0.45	0.75	1.05	0.9

Based on a reference of FAO (1986)

Table 5 Growth period of four growth stage in several vegetables

	Growing period (days)				
Crop	total	initial stage	development stage	Mid season stage	late season stage
Tomato	135	30	40	40	25
Onion	150	15	25	70	40
Chili pepper	105	10	35	40	20
Cucumber	105	20	30	40	15
Gumbo	-	-	-	-	-
Cabbage	120	20	25	50	30
Carrot	100	20	30	30	20

Based on a reference of FAO (1986)

Table 6 Maximum irrigation requirement during cultivation period in several vegetables

Cultivation start month	Tomato (135 days)	Onion (150 days)	Carrot (90 days)	Cabbage (120 days)	Pepper (120 days)	Cucumber (105 days)
	maximum irrigation requirement during cultivation (mm/day/m2)					
Jan	7.6	7.7	7.3	7.7	7.7	6.6
Feb	7.5	7.7	7.4	7.7	7.7	6.6
Mar	5.8	7.0	6.2	6.6	6.0	5.6
Apr	4.0	5.3	4.7	5.0	3.8	4.1
May	2.1	3.2	2.7	3.0	1.8	2.5
Jun	4.0	4.2	1.1	1.4	0.2	0.9
Jul	5.2	4.9	4.5	4.9	4.8	3.7
Aug	5.6	5.3	5.0	5.3	5.3	4.5
Sep	5.5	5.7	5.4	5.7	5.7	4.9
Oct	6.1	5.8	5.3	5.8	5.6	4.7
Nov	6.8	6.5	5.9	6.4	6.3	5.3
Dec	7.5	7.2	6.6	7.1	6.9	5.9

Table 7 estimated available cultivation area in pilot-family

	Available cultivation area (m^2)				
	Tomato (Apr start)	Chili pepper (Apr start)	Onion (Aug start)	Carrot (Jan start)	Cucumber (Jan start)
DA concession	99.0	102.6	73.4	53.4	59.4
CE concession	20.3	21.1	15.1	11.0	12.2
IE concession	47.0	48.7	34.8	25.3	28.2

Table 8 income estimation per 10 m^2 in several vegetable

	target yield		estimated yield		filling rate			wholesale price	income
	t/10a	plant/10a	factor	kg/10 m^2	g/cm^3	rate	L/10m^2	(farmer to broker)	FCFA/10m^2
Tomato	10		0.8	80	1	60%	112	17,500FCFA/200L	9,800
Onion	6	30,000	0.8	48	1	60%	67	8,750FCFA/40L	14,700
Chili pepper	4		0.8	32	0.8	60%	56	5,500FCFA/40L	7,700
Courgette	6		0.8	48	1	60%	67	9,750FCFA/40L	16,380
Gumbo	2.5		0.8	20	0.8	60%	35	4,000FCFA/40L	3,500
Cabbage		5,000						75FCFA/plant	3,750
Carrot		30,000						10,000FCFA/10 m^2	10,000

Table 9 maximum income estimation per year in pilot-family

	income estimation FCFA						Maximum income/year	
	Tomato	Chili pepper	Onion	Carrot	Courgette	Gumbo	FCFA	EURO
DA concession	97,005	79,026	107,966	53,425	97,233	34,645	336,849	518
CE concession	19,898	16,211	22,147	10,959	19,945	7,107	69,097	106
IE concession	46,015	37,487	51,215	25,342	46,123	16,434	159,787	246

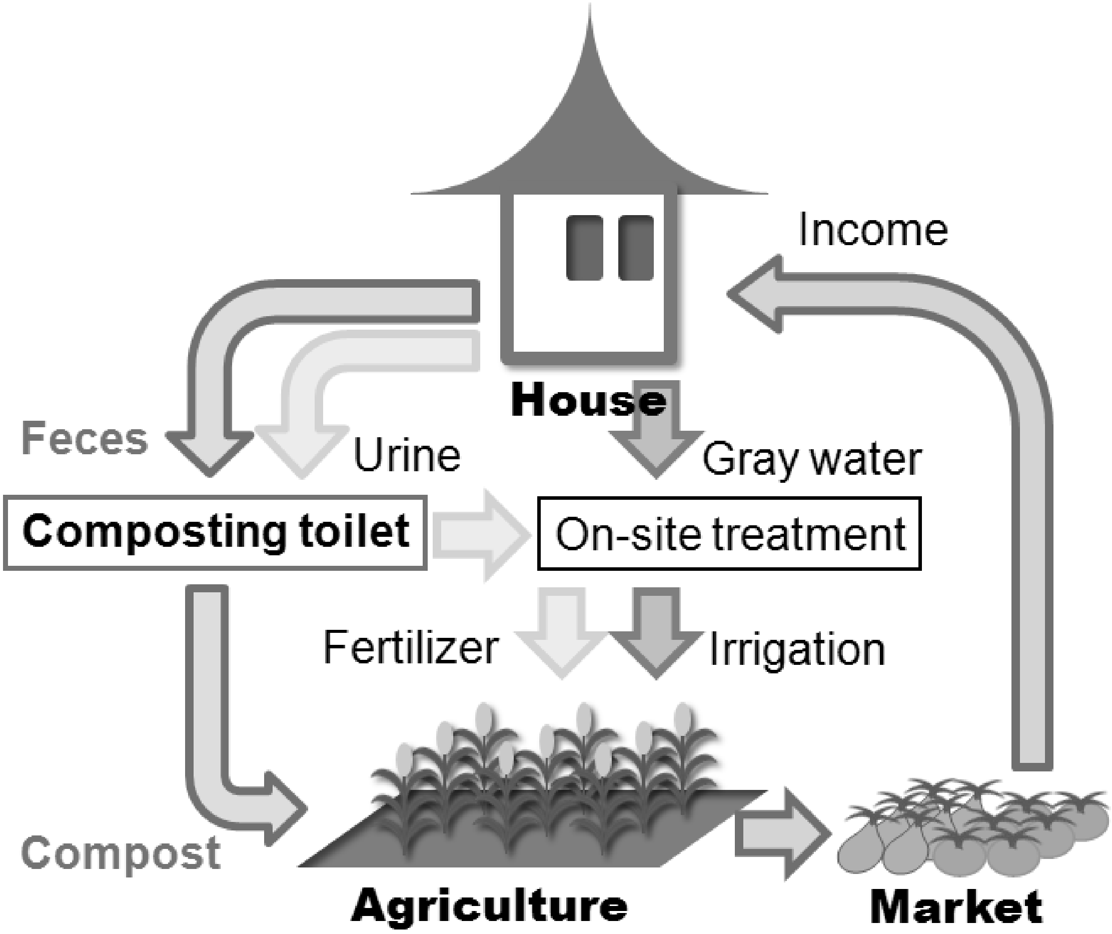

Fig. 1 scheme of decentralized and resource recycling based sanitation system in rural area, Burkina Faso

Fig. 2 Composting toilet (A) and slanted soil system for greywater treatement (B)

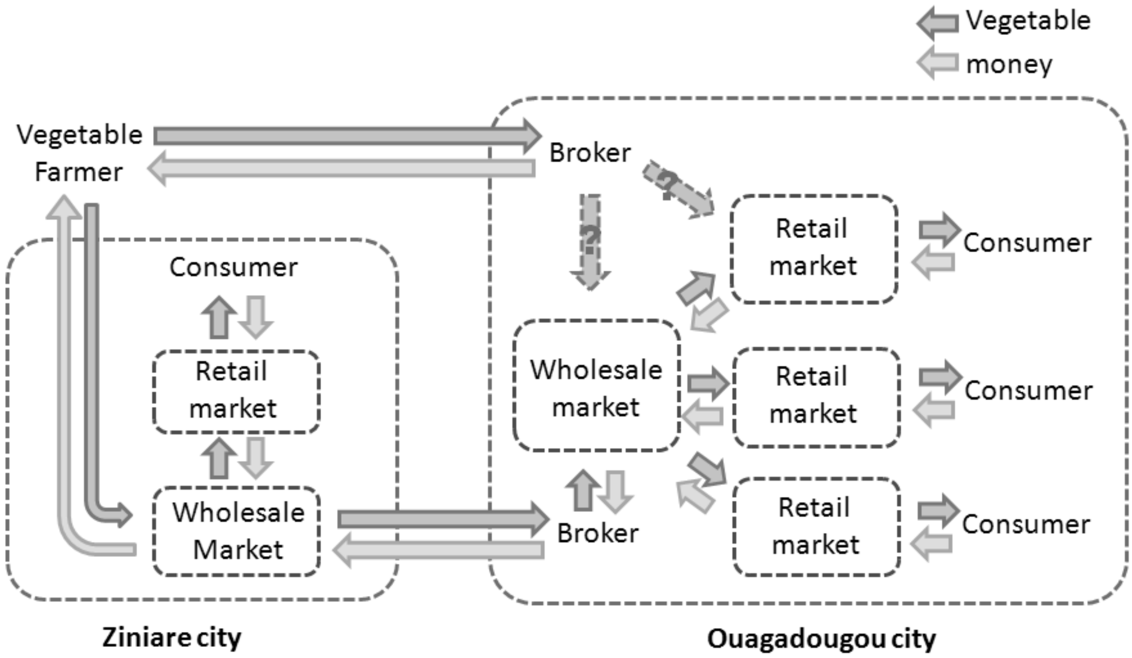

Fig. 3 vegetable distribution system in rural are, Burkina Faso

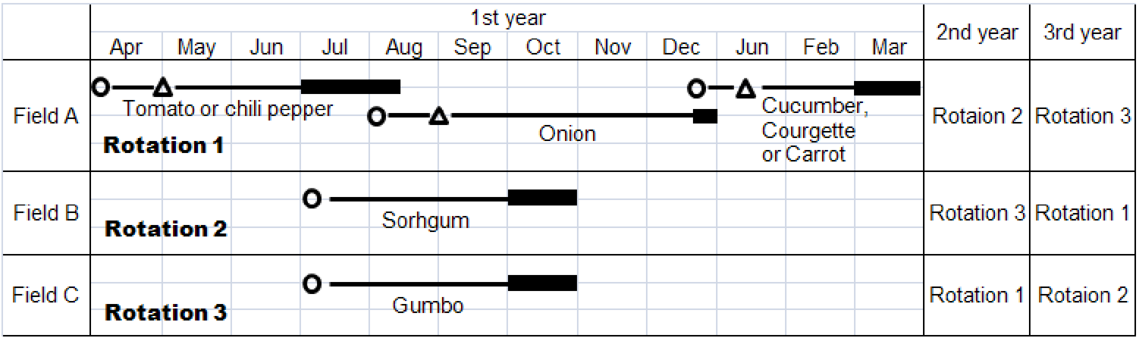

Fig. 4 One model of crop rotation in Ziniare