SATNET Asia Technology Validation Study

Ecosanitation
"Phaydemand Shauchalay"
The Beneficial or Productive Toilet

Study conducted by **Janis Koknevics**

Report compiled by **Dr. S. K. Kriesemer**

Food Security Center, University of Hohenheim

October 2014

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The Network for Knowledge Transfer on Sustainable Agricultural Technologies and Improved Market Linkages in South and Southeast Asia (SATNET Asia) aims to support innovation by strengthening South–South dialogue and intraregional learning on sustainable agriculture technologies and trade facilitation. Funded by the European Union, SATNET facilitates knowledge transfer through the development of a portfolio of best practices on sustainable agriculture, trade facilitation and innovative knowledge sharing. Based on this documented knowledge, it delivers a range of capacity building programmes to network participants.

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1. Introduction

Worldwide more than one billion people have to defecate in the open (e.g. in gutters, behind bushes or in open water bodies), which is one of the clearest signs of extreme poverty. Globally, about 2.5 billion people (one third of humanity) still do not have access to proper sanitation, like toilets or latrines, which has severe negative effects on human health, dignity and security, the environment, and social and economic development. Open defecation causes the spread of diseases like cholera, typhoid, hepatitis, polio, diarrhoea, and worm infestations(UN, 2014). Diarrhoea is one of the main causes of death in children under the age of five years. In India alone, 12.6% (absolute number of 212,000) of deaths of children of this age group were caused by diarrhoea in 2010 (Liu et al., 2012). The contamination of drinking water with faecal matter thereby reduces the physical growth, impairs cognitive functions, particularly of children and causes undernutrition (UN, 2014).

The Millennium Development Goal target on Water and Sanitation aims to reduce the global share of population without access to improved sanitation from 51% in 1990 to 25% in 2015. Open defecation has reduced from 24% to 14 % by 2012 (WHO & UNICEF, 2014). Still, sanitation is considered one of the two most off-track MDG targets globally (UNSGAB, 2015).

Although 291 million people gained access to improved sanitation in India between 1990 and 2012, still 792 million people had no access to an improved sanitation facility in 2012 (Figure 1). Globally, India continues to host the highest number (597 million people) of people practicing open defecation (WHO & UNICEF, 2014). India is not on track towards the MDG target. The Government of India launched the so-called “Total Sanitation Campaign” in 1999 and up to 2011, 73% of the rural population have been covered in India (UNICEF, 2011). However, sanitation coverage differs between states and between rural and urban areas. In rural areas of India, the percentage of people defecating openly has devreased from 90% in 1990 to 65% in 2012 and the share of people having access to improved sanitation increased from 7% to 25%. In Indian cities, 60% of the population had access to improved sanitation while 12% used open defecation in 2012. These figures highlight the inequality in terms of access to sanitation between rural and urban areas.

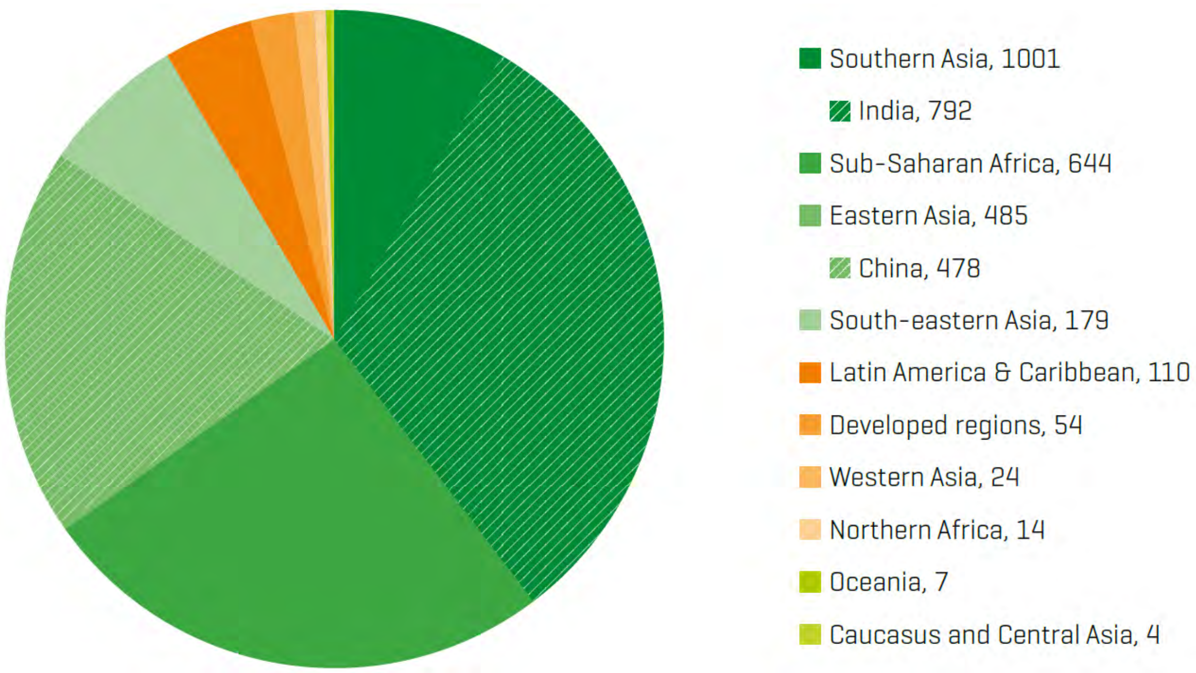

Figure 1: Number of people (in millions) without access to an improved sanitation facility in 2012, by

MDG region

Access to sanitation is very limited in rural Bihar, one of the poorest states of India, and open defecation is common practice. Bihar has the highest urban poverty ratio (43.7%) of India and the second highest rural poverty ratio (55.7%). Ninety percent of the total population live in rural areas. The state of Bihar is also a flood prone area with over 73% of the total geographical area regularly flood affected (UNDP, 2011). During floods, unsafe sanitation practices contribute to water borne diseases and lead to increased use of land on high ground (i.e. embankments) for open defecation, further exacerbating the conditions in which people are forced to live.

Especially for women and adolescent girls the lack of proper toilettes is creating difficulties. In search of privacy, they prefer to defecate in the dark, before and after sunset. They have to walk for long distances, which exposes them to the risk of being aggressed or harassed physically or verbally (Megh Pyne Abhiyan, 2008). Many adolescent girls drop out of school when they start menstruating because without toilets they have no privacy (UN, 2014).

The UN General Assembly and the Human Rights Council recognized safe sanitation and clean drinking water as a human right. They are essential to the full enjoyment of life as well as all other human rights (UNSGAB, 2015).

1.1. Sustainability issues of current sanitation approaches

Open defecation contributes to the pollution of surface and ground water which exacerbates the shortage of freshwater that many areas of the world already face today. Globally, about 80 countries with 40% of the world's population suffer from seasonal water shortages by now. Globally, the number of people facing water scarcity in 2025 is estimated to increase to 3 billion (Corcoran et al., 2010). In developing countries, roughly 80 to 90 % of wastewater flows directly into surface water bodies like rivers, lakes, and seas without any treatment. The river basin of Ganges, Brahmaputra, and Meghna alone receives 94 billion cubic meters of wastewater every year and is considered a severely deteriorated ecosystem (Corcoran et al., 2010).

There are two broad types of sanitation that are currently in used: the so called "flush-and-discharge" type and the "drop-and-store" type of toilet (Esrey et al., 1998). The "flush-and-discharge" type was long perceived as the ideal approach to sanitation, a "modern" approach that was associated with the notion of a developed civilization. This type of sanitation requires high amounts of flush water (15,000 l of usually fresh water to flush 400 to 500 l of urine and 50 l of faeces per year per person), the necessary infrastructure composed of a pipe system for fresh water, a sewage system so collect the wastewater and treatment plants, as well as technical skills to operate the whole system. However, such services are often unavailable or non-operational in developing countries which leads to environmental pollution (e.g. nutrient overload of water bodies, toxic algae blooms) (Esrey et al., 1998).

The "drop-and store" type of sanitation is most commonly a pit toilet for containment and indefinite storage of human excreta. It can prevent environmental pollution in some places but is not suitable for all locations. Particularly in urban areas the adoption of "drop-and-store" sanitation is difficult because of the need and difficulty of digging deep pits, possibly destabilizing nearby houses, difficult soil and groundwater conditions, and odours (Esrey et al., 1998).

Both described types of sanitation follow the paradigm of a linear system of sanitation where faeces are the end product and are considered as waste. "*The current sanitation paradigm is* *failing the world, with the poor suffering most, threatening the integrity of fresh water supplies, and in general creating unsustainable linear flows that can ultimately make life on earth difficult or no longer feasible. The problems with conventional sanitation are fundamental, and a radically different approach is needed*" (UNESCO IHP & GTZ, 2006).

1.2. Ecological Sanitation

An approach to overcome the shortcomings of both traditional types of sanitation is ecological sanitation, or the "sanitize-and-recycle" type of sanitation (Esrey et al., 1998; UNESCO IHP & GTZ, 2006). While ecosanitation can be applied to different substances (urine or "yellow water", faeces or "brown water", organic waste from the household kitchen, household wastewater or "greywater" from showering and washing, and rainwater) (UNESCO IHP & GTZ, 2006), the focus of this study lies on the treatment of urine and faeces. The ecosan approach treats human excreta as a resource rather than a waste and creates a closed nutrient cycle in which sanitized faecal matter is used as fertilizer in agriculture (Figure 2). "*Ecological sanitation replicates nature by returning sanitized human urine and faeces to the soil. Instead of polluting the environment, human urine and faeces are used to improve soil structure and supply nutrients*" (Esrey et al., 1998).

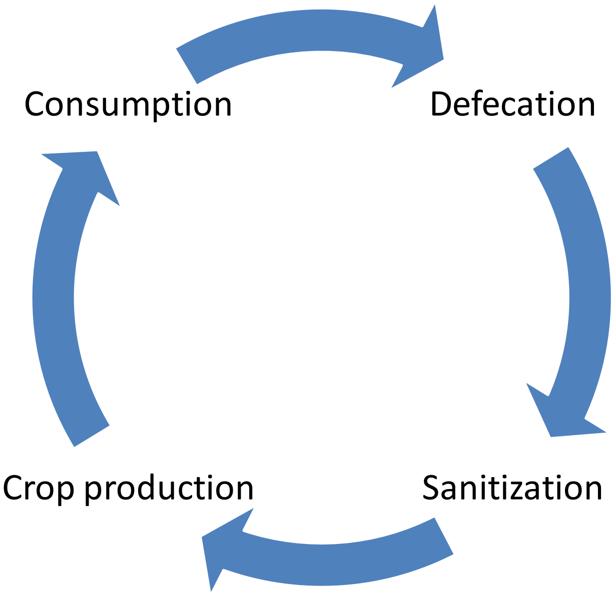

Figure 2: Nutrient cycling in ecological sanitation

It is essential to sanitize human excreta before use in agriculture, especially to disrupt the life cycle of pathogens contained in faeces. While urine is usually hygienically uncritical and contains most of the nutrients valuable for fertilization, the fresh faeces contain pathogens like e.g. bacteria, viruses, protozoa, nematodes, and worm eggs (UNESCO IHP & GTZ, 2006). Several methods can be used to recover the resources from human excreta (Esrey et al., 1998): For urine they are:

- **Diversion** (urine and faeces are collected separately and never mixed). This method is implemented in North Bihar where the focus of this study lies.
- **Separation** (urine and faeces are mixed and subsequently separated from each other)
- **Combined processing** (urine and faeces are collected, processed and re-used together)

For faeces possible sanitization methods are:

- **Dehydration** (drying)
- **Decomposition** (breakdown of components including pathogens into smaller parts)

Both usually occur simultaneously to some extent. The methodological distinction considers which one is used predominantly and contributes most to sanitize the faecal matter.

A toilet must be hygienic, safe, environmentally friendly, and affordable (Rajbhandari, 2011). In particular it must be able to destroy or isolate pathogens, it must prevent pollution, save water resources and return valuable nutrients to the food system, and must be accessible to poor households, particularly in developing countries. In addition, a toilet must be acceptable to its users (be in line with cultural norms and values and aesthetically inoffensive) and simple (robust, easy, and cheap to operate and maintain) (Esrey et al., 1998).

An ecosan toilet is a new, odourless and integrated method for sanitation which saves water and manages waste efficiently. It considers human waste as a valuable and useful resource. Excreta like urine and faecal matter as well as wash water are separated and then used as fertilizer on the field. This approach reduces water pollution and mitigates the health risk to humans. Separating the components and avoiding the use of flush water considerably reduces the volume of waste to be treated. Ecosan systems can easily and safely be adopted in a decentralized manner, by individual households. Decomposed faecal matter can improve the structure and water holding capacity of soils and replace costly mineral fertilizer and hence help reducing production costs. These systems are energy efficient and cost effective. Consequently, ecosanitation can considerably contribute to health, food and nutrition security, particularly of poor households (UNICEF, 2011).

The human waste of one year contains enough nutrients to produce 250 kg of rice, which corresponds with a person's staple food requirement for one year (UNESCO IHP & GTZ, 2006).

This technology recycles wastes and contributes to the creation of local and closed nutrient cycles within villages.

1.3. Background and focus of this study

Bihar ranks 21 out of 23 Indian states in terms of its Human Development as per the India Human Development Report. Agricultural productivity lies far below the national average (rice yield in Bihar: 1,237 kg/ ha, national average rice yield: 2,202 kg/ ha). The average land holding size is very small with only 0.58 ha; more than 80 % of farmers operate on 0.30 ha. Almost 55 % of children are underweight (UNDP, 2011).

The ecosan units described here are promoted and implemented in Bihar by Megh Pyne Abhiyan (MPA, English name "Cloud Water Campaign"), since 2007, when the group was an informal network of local organizations and professionals and a campaign. It was in 2012, that the campaign got registered as a Public Charitable Trust. MPA was first introduced to ecosan by Mr S. Vishwanath (Biome Environmental Solutions Pvt. Ltd.) in a water workshop (Jal Manthan Shivir – Water Brainstorming Workshop) organized by MPA.

Ecological sanitation was promoted in North Bihar first by a participatory process of adaptation of the concept to local conditions and needs and second by training and supporting interested households. A total of 78 households adopted ecological sanitation and are still using the toilets up to today.

The particular ecosanitation technology promoted in North Bihar and examined in this report is locally called “Phaydemand Shauchalay”, meaning beneficial or productive toilet. It is designed to withstand floods and is therefore particularly adapted to the local conditions in North Bihar. It has a brick/cement base structure and either a super-structure made of bamboo and woven grass mats (Figure 3) or of more solid but more expensive brick walls. The toilet has two excreta collection chambers, one urine outlet and two anal wash water outlets. When one excreta chamber is full, it is closed and faeces are left to decompose over a period of six months or more, while the second excreta chamber is used.

1.4. Objective statement

The purpose of this study was to investigate the sustainability of the ecological sanitation (ecosan) units promoted and implemented by Megh Pyne Abhiyan (MPA). For this study three districts in North Bihar where MPA works were visited, namely, Paschim (West) Champaran, Saharsa and Khagaria.

This assessment is based on the four dimensions of sustainability following the SATNET Asia analytical framework and the technology will be analyzed from a social, technical, economic and environmental point of view.

Figure 3: Ecosan toilet in Rupaliya, with mud, straw and bamboo super-structure (Photo: Janis Koknevics)

Figure 4: Inside of full brick and cement ecosan in Rupaliya (Photo: Janis Koknevics)

Note: Central hole used for urine, covers on either side for defecating and the holes on the extreme right and left side of the picture for cleaning oneself after the toilet. Ash is applied on the excreta after defecation (right corner of the picture).

The remainder of the document begins with a brief literature review on sustainability and sustainability assessments in agriculture, followed by the description of material and methods used for data collection before presenting the results and conclusions. The Document concludes with a summary and the annex contain the survey questionnaire used for interviews.

2. Sustainability and sustainability assessments in the agriculture sector

The term sustainability (“Nachhaltigkeit” in German) is not new and was first reported by Mr. Hans Carl von Carlowitz (1645-1714) in his publication on forestry „Sylvicultura oeconomica“ in 1713 and the principle was described later by Thomas Robert Malthus (1766-1834) in “An Essay on the Principle of Population” in 1798. In the so called Brundtland Report “Our Common Future” sustainable development was defined as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (World Commission on Environment and Development, 1987).

Similar to the Brundtland Report ’s definition of sustainable development, FAO puts forward the following definition: "Sustainable development is the management and conservation of the natural resource base and the orientation of technological and institutional change in such a manner as to ensure the attainment and continued satisfaction of human needs for present and future generations. Such sustainable development (in the agriculture, forestry, and fisheries sectors) conserves land, water, plant and animal genetic resources, is environmentally non-degrading, technically appropriate, economically viable and socially acceptable." (This definition was adopted in 1989 by FAO, according to FAO (1995).

Hence, FAO – as most organizations – uses the concept of weak sustainability: “Substitution of resources will be possible as future generations substitute resources that are relatively more abundant for those that have grown scarce. In agriculture, the substitution of human capital – in the shape of knowledge about improved technologies – for land and labor, has been important in the past and will be at least as important in the future” (Hardaker, 2002). In the case of strong sustainability, the substitution of natural capital by human capital is not possible. In contrast to weak sustainability, the strong approach requires that human-made and natural capital are treated as different categories that need to be preserved separately for the coming generations (Hansson, 2010).

In 2012, the United Nations agreed on the development of Sustainable Development Goals for the post 2015 era (UN, 2012). These goals and their measurable targets and indicators will help advance all nations (North and South) on the road towards sustainable development. “*Metrics are needed to set base-lines against which to measure progress, track and predict socioeconomic, nutritional, and ecological change; understand constraints to sustainable development; work successfully with public, private, and NGO partners; and identify appropriate policy measures*” (SDSN, 2013).

The landscape of sustainability initiatives is diverse and many approaches to sustainability assessment have been developed in the past (Doluschitz & Hoffmann, 2013). For sustainability assessments in the agricultural and food sector, different frameworks for different purposes were developed by research and the private sector looking at partial aspects of sustainability with different foci on parts of the value chains or food system.

The level of aggregation of the results differs from composite sustainability indices (CSI) (Dantsis, Douma, Giourga, Loumou, & Polychronaki, 2010; Gómez-Limón & Sanchez-Fernandez, 2010; Krajnc & Glavič, 2005; Saisana, Saltelli, & Tarantola, 2005) toward more disaggregated representations of results in sustainability polygons (FAO, 2013; Häni et al., 2007). The SATET Asia analytical framework uses both, a composite sustainability index to compute a ranking of about 30 agricultural technologies assessed and radar charts to visualize and interpret results (Kriesemer et al., forthcoming; Kriesemer & Virchow, 2012).

In an attempt to harmonize the landscape of sustainability assessment the United Nations’ Food and Agriculture Organization (FAO) has recently published the guideline for a Sustainability Assessment of Food and Agriculture (SAFA) systems. This framework aims to be a holistic global reference framework for the assessment of sustainability along agriculture, forestry and fisheries value chains Fair playing field for all by presenting a framework adaptable to all contexts and sizes of operation

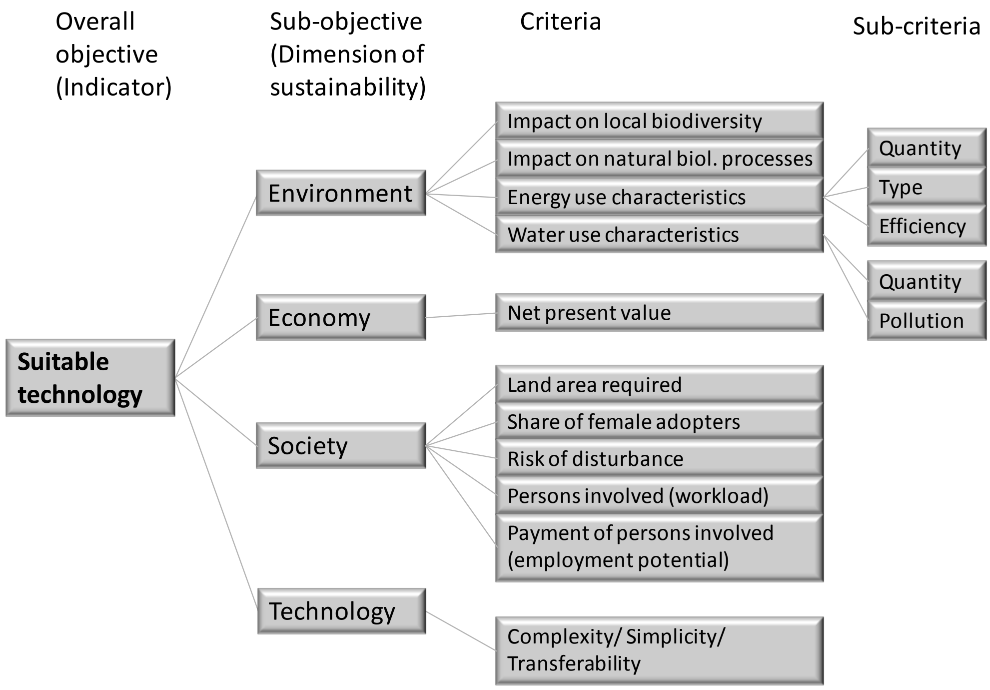

Figure 5: Criteria used in the SATNET Asia sustainability assessment

3. Material and Methods

The section provides an indebt description of each tool that was used in this study and how each step allowed answering the questions posed for sustainability assessment of the ecological sanitation toilet in North Bihar, India.

3.1. Interviews with Key Informants of Ecological Sanitation in the Region

People who are directly involved in the promotion and distribution of the ecological sanitation toilets, long term users of the technology, engineers, community leaders and others working in the field of sanitation were interviewed. They provided a long term account of the development of the technology in the region, its past and present challenges and outlook for the future.

Local, foreign NGOs and specialists working on sanitation projects were contacted either directly or by phone, as best possible to provide the study with ample input from all parties involved in the similar field of study or work.

3.2. Questionnaire based Survey

The questionnaire survey comprised two separate groups of persons. The first group were the users of the ecological sanitation toilet. This survey assessed the current situation of the technology, its reception amongst its users, the social changes that have occurred since its introduction and the financial consequences, and environmental impacts to the community and land. The second group were members of the community not using the ecological sanitation toilet. This provided the study with an account on people's perception of the technology and their reasons for not adopting it. The questionnaire for the non-users of the ecological sanitation toilet was used to interview those that have seen the toilet itself, therefore preferably neighbours to people who own one of these toilets.

Specific questionnaires were developed for both groups, translated from English to Hindi, and then translated back from Hindi to English by another person to verify that information was not lost or distorted during translation. A pilot surveys was carried out at the beginning of the research period to pre-test the survey tool. This allowed to assess the data collected, to add any questions that might previously have been missed out and to confront any difficulty identified through the pre-test.

The study sites were in North Bihar, in three villages located near Khagaria city, Saharsa city and in Paschim (West) Chaparan. These locations were chosen purposively because of the promotion activities implemented by MPA in these villages. Depending on the number of villagers and accessibility to their households either all were interviewed or simple random sampling was used to select participants for the study.

3.3. Focus Group Discussions

Focus group discussions were carried out in each study village on the last day, when all interviews have been conducted. Through open discussion, participants were allowed to express themselves on the importance of the toilet, its benefits and limitations, how to improve it, and promote better. This allowed participants not owning a toilet to express perception about the technology. Finally, whenever possible, preliminary results obtained from the interviews were discussed with the participants, to get their feedback on whether they feel the preliminary results correctly represented the reality.

3.4. Field Observations

Field observations were invaluable in visiting the various ecological sanitation toilets, gathering photographic evidence and meeting the community members using the technology. These visits happened during the survey time, but during free time, which allowed for observing on critical points such as cleanliness of the toilets, functional situation and the general household life. These reflections were gathered in a field book, which served to note personal perception of sites and households visited.

3.5. Villages and Interviews Conducted

The field research was conducted between 19.05. and 29.07.2014. Expert interviews were conducted with local water and sanitation experts in Delhi, MPA representatives from various districts in Patna, Bihar and stakeholders at local government level in Paschim (West) Champaran as well as local NGO field workers and representatives in Paschim (West) Champaran, Saharsa and Khagaria. A pre-test was conducted with four households in three villages in the Nautan block of Bihar. A total of 53 interviews with ecosan users were conducted (Table 1).

3.6. Data analysis and indicator calculation

Data analysis was done using MS EXCEL and SPSS. The composite sustainability index was calculated following the SATNET Asia analytical framework: To decide on the relative importance of the criteria under consideration, a criteria weight distribution was developed in consultation with a team of interdisciplinary scientists and project partners. The table below shows all essential criteria and their corresponding weights assigned to them by consensus.

Table 1: Locations and interviews conducted

Location	Type of interview	Persons interviewed
3 villages in Nautan block (Paschim (West) Champaran district)	Pre-test	4
Rupaliya village (Paschim (West) Champaran district)	Interview with ecosan users	21
	Informal interview with future ecosan users (toilets under construction)	10
	Informal interview with persons interested in ecosan units	3
5 villages in Saharsa district	Interview with ecosan users	8
Khagaria village (Khagaria district)	Interview with ecosan users	24

Table 2: Weights assigned to dimensions, criteria, and sub-criteria of the framework

Dimensions	Weight	Criteria	Weight	Sub-criteria	Weight
Environment	0.3	Water consumption	0.35	Water quantity	0.5
				Water pollution	0.5
		Energy Consumption	0.35	Energy quantity	0.33
				Type of energy	0.33
				Energy use efficiency	0.33
		Impact on nat. biol. processes	0.15		
		Impact on local biodiversity	0.15		
Society	0.3	Number of people involved [1]	0.15		
		Payment of people involved [2]	0.15		
		Risk of disturbance	0.1		
		Share of female adopters [3]	0.3		
		Land area required [4]	0.3		
Economy	0.3	Net present value	1.0		
Technology	0.1	Complexity, simplicity, transferability	1.0		

Note: [1] represents workload, [2] represents employment potential, [3] represents vulnerable groups, [4] represents suitability for poor landless people

To calculate the composite sustainability index, the sum of all weighted and normalized criteria values was built:

$$CSI = \sum_{i}^{n} w_i \cdot cv_i \qquad (1)$$

where CSI is the composite sustainability index, *w* is the weight of criterion *i*, and *cv* is the criteria value of criterion *i* (compare Krajnc and Glavič, 2005).

4. Results

4.1. Rupaliya

One toilet is mainly used only by one household, which consists of 4 to 10 persons. On average, they consisted out of around seven children per household with half of them over 16 years old. On average a household needed eleven months to adopt the ecosan toilet after hearing about it for the first time. Mostly the adoption delay was due to health problems, organisation problems or they were just not yet ready for it, not properly understanding the technology or not yet seeing it as a useful technology. For the construction of the toilettes around four to five paid workers were needed for an average of four days per household. They were paid approximately 200 INR per day, which corresponds to US$ 3.66[1]. The material costs contributed by the household were around 1,955 INR ($US 36). The costs for construction of the sub structure, including squatting pans and pipes were borne by the promoting NGO. On average, it took adopters one month to construct one toilet, though some needed only seven days, others 150 days. The main difficulty in building a toilet was the availability of labour.

The ecosan users in Rupaliya stated benefits of saving 1 to 2 hours/day by not having to go for open defecation, time which is now used for household chores, farming, education or relaxing. Safety of the family was also mentioned as both a benefit and reason for adoption of the ecosan toilet. The use of urine as a fertilizer has been positively received in the village. Farmers observed greener crops and higher yields through individual experiments at household level by applying urine to some crops and chemical fertilizers to others. Through urine application instead of fertilizer, households saved one to two bags of urea and up to 2000 INR ($US 37). The saved money was used for personal and household utensils, vegetables or additional fertilizer. Two households stated that they sell urine for 20-30 INR per litre ($US 0.37-0.55). None of the households used their own composted excreta for farming yet, but they consider using it in future.

The main maintenance issue that was observed and identified by a majority of respondents was the presence of worms in the excreta chambers. Worms develop when water or urine is mixed with excreta. Respondents stated that children have difficulties with urinating and defecating separately and that water might have entered the excreta chamber accidentally when washing oneself. The presence of water is leading not only to the development of worms but also increased smell in the toilet.

Generally, the smell of the toilet was quoted as good, with only few households mentioning bad smell. The use of the toilet happens in privacy and most of the adopters persuade others to have an ecosan toilet as well. Before they adopted this technology, they went up to 60 minutes for defecation in the open fields in morning and evening or darkness. In doing so, most of them felt unsafe.

Mostly females are cleaning the toilets, while emptying the urine basket is mainly the job of males. The urine is not applied on religious trees, mango trees or leafy vegetables.

To the question how the technology could be improved, they quoted that the stairs were too small and there was the risk of falling. Some would build the excreta hole higher, so that no water can enter it easily. Though there are adopters in Rupaliya, some people still don’t want to eat vegetables, fertilized with urine.

[1] All currency conversions were made using the OANDA currency converter on www.oanda.com at the conversion rate of 31.03.2013, the standard conversion rate for SATNET Asia data.

Figure 6: Full brick and cement structure in Rupaliya(Photo: Janis Koknevics)

The drawing painted on the ecosan toilet demonstrates the cycle from defecating to applying urine and humanure to crops.

4.2. Saharsa

Respondents in Saharsa reported safety of the family, having a toilet at home and saving time by not going to the fields as beneficial. Three households stated using urine as fertilizer observing higher yields and greener crops. One respondent stated using humanure in his fields and observed “greener crops and no issues with insects”.

Maintenance issues were more prominent in Saharsa than in Rupaliya, with three households gas pipes missing or broken (meant for evacuating smell from the excreta chambers) increasing smell in the toilets, two households urine taps missing or broken and one household with no roof for the toilet.

4.3. Khagaria

There are a number of large rivers surrounding the district, which lead to regular floods, loss of life and property. The village itself is located outside the embankments protecting Khagaria city and the village is made up off a majority of migrant workers and landless people. In Khagaria village, MPA installed 40 ecosan units.

Ecosan users stated benefits of saving one to three hours/day not having to go for open defecation, using that time for household chores, cooking and relaxing. Safety of the family was noted as being very important and regular access to the ecosan as beneficial, especially during sickness and monsoon. Six of the households stated not owning any land and 18 leasing one kattha (126 m^2, varies in size from one part of India to the other) or more. Six households stated having used urine at least once for their crops, and observing greener, stronger crops.

The majority of the ecosan units observed where built with a brick and cement sub-structure and bamboo/mud super-structure, three ecosan units were fully built out of bricks and cement. Urine chambers were fitted with plastic taps for easy access, however six of them were broken, likely cause that people used them as step to climb into the toilet, as some ecosan units did not have steps installed. Some households owned more than one ecosan unit, due to sons marrying and constructing their own ecosan unit. However most families had an agreement to use one ecosan unit collectively until it is full and then use the 2nd ecosan unit. Ecosan units which were not currently in use were used for storage of corn stalks, water filters, drying clothes and straw (Figure 7).

Figure 7: Straw, corn stalks, rice husks stored in unused ecosan unit (Photo: Janis Koknevics)

The presence of water in the excreta chambers and blocked urine pipes with debris was the cause of the children as stated by most respondents. Erosion of the soil supporting the structures was observed in at least eight ecosan units located on slightly sloped ground, which could become a problem for the integrity of the structure (Figure 8).

Figure 8: Erosion, exposing the brick base layer (Photo: Janis Koknevics)

4.4. Sustainability criteria and composite sustainability index

The values of criteria and sub-criteria used for composite sustainability index calculation are listed in Table 3.

Table 3: Key sustainability criteria and sub-criteria

Sustainability criteria and sub-criteria	Data and estimates of this study	MPA data and estimates
Quantity of water used	Very little	Very little
Water pollution	Slightly pollutes water	No water pollution
Energy use	No energy used	No energy used
Impact on natural biological processes (e.g. like photosynthesis, soil mineralization)	highly positive impact	Very positive impact
Impact on biodiversity	Positive impact	Very positive impact
Work load	55 hours per year	55 hours per year
Employment potential	No	No (yes)
Risk of disturbance	Low risk through odour when not well operated	Low risk through odour when not well operated
Gender[2]	45 % of female adopters	50% of female adopters
Minimum land area required to adopt the technology	2.499 m^2	2.52 m^2
Initial investment costs (US$)	157.60	310.41
Net Present Value (US$)	93	-168
Complexity	Easy to understand and use	Easy to understand and use

The work load is very low. In the SATNET Asia data set of 30 technologies only two other technologies required even less work per year (they were backyard poultry rearing and cricket farming). The estimation of this study was copied to the MPA data set for indicator calculation. The initial investment costs stated by respondents in this study (US$ 158) comprise the labour and material to construct the super-structure of the ecosan unit. The sub-structure and squatting pan were provided by MPA. For this reason the initial investment

[2] 47.9 % of Bihar's total population are women: there are 919 women per 1000 men.

costs stated by MPA for an ecosan unit considerably higher (US$ 310). The estimation of gross value and variable costs is very difficult. Gross value and variable costs were estimated from the data collected during this study but not provided by MPA. For this reason, the data from this study was copied to the MPA data for indicator calculation. The estimation of gross value and variable costs is very difficult. The gross value is likely to be underestimated due to the many external and non-monetary benefits like savings of costs for fertilizer, savings of medical expenses, saved time, security, privacy and dignity. The technology was estimated to be easy to understand and use with not much knowledge required to successfully operate it.

The ecosan unit ranks at positions 7 (this study data) and 10 (MPA data) out of 32 technologies included in the SATNET Asia data set. The composite sustainability index is 0.168 and 0.138 for this study's and MPA data, respectively. In comparison, vermitechnology which has the highest CSI of the SATNET technologies scores at 0.494. These figures as well as the data presented in Table 3 and Figure 9 reveal that the estimates and data provided by MPA are close to the results generated by this study. In general, the closer the radar line is to the outer edge of the graph, the better the technology scores regarding the criterion in question. The larger the area inside the radar line, the higher its sustainability.

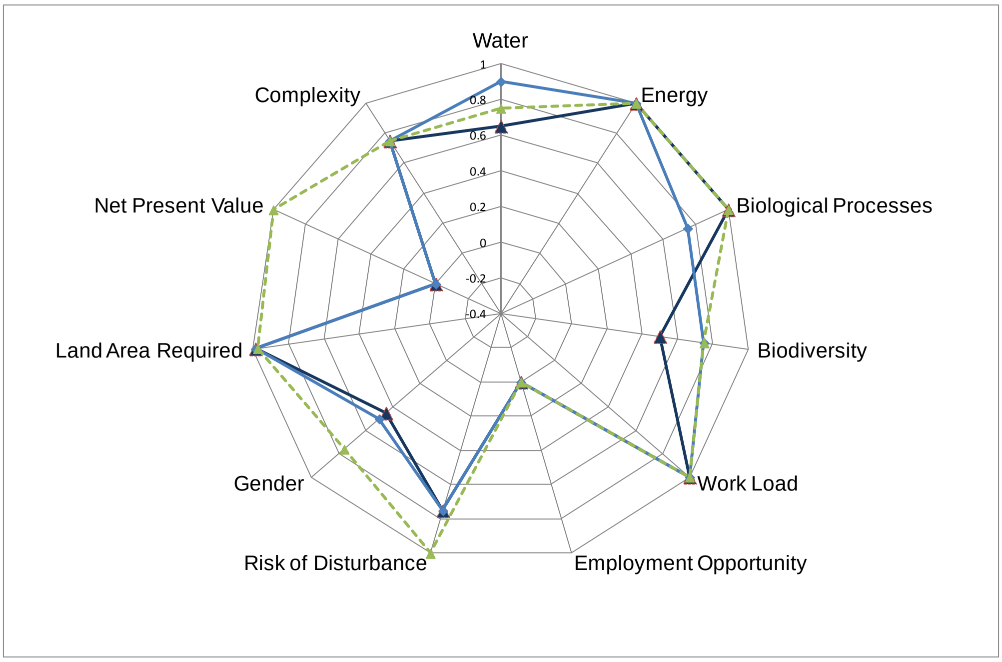

Figure 9: Radar chart on criteria results of ecosanitation (blue: this study, dark blue: MPA data) and vermitechnology in comparison (green dashed line)

In comparison with vermitechnology, ecosanitation is characterized by similarly positive results regarding water and energy use, the technology's impact on biological processes and on biodiversity, the little land area required, and a low work load. Ecosanitation scores less compared to vermitechnology in terms of the risk of creating social conflicts or rejection in the neighbourhood, the share of female adopters using ecosanitation and in terms of the economic output. The valuation of financial benefits of ecosanitation was not possible because excreta were still in the process of decomposition and adopters had hardly started using and selling humanure.

5. Conclusions

In all three districts, a vast majority of people who had adopted the ecosan toilet, were using and maintaining it appropriately and where satisfied and saw it as an improvement to their livelihoods.

Based on the composite sustainability index calculation ecosanitation as observed in North Bihar can be regarded as a sustainable technology, suitable for poor and vulnerable people. The results also show that the estimates and data provided by MPA are close to the results generated by this study. The valuation of financial and agronomic benefits of ecosanitation remains to be done in the future.

Observations revealed that the maintenance status and use of the ecosan units differed as a function of the geographical location, remoteness, and educational level of the villagers. The villagers in Khagaria stated that access to construction materials for ecosan units was easy; however, MPA workers stated that getting the work done in Khagaria was comparatively much harder due to accessibility of the village.

Whether the promotional efforts of MPA will generate a long term and sustainable change in defecation behaviour of users, whether the physical units can withstand regular floods, and how long they will be functional before major renovations or rebuilding becomes necessary, remains to be seen.

Also more experience will have to be made regarding the optimal use of humanure in home gardening and other agricultural activities. Agronomic and socioeconomic research can help to monitor and evaluate the experiences made by ecosan users in North Bihar.

6. Summary

Open defecation is one of the clearest sign of poverty and remains a common practice in many developing countries and in Bihar (India) in particular. The state is regularly affected by floods which make safe defecation more difficult in absence of improved sanitation options. Open defecation leads to the spread of many diseases which affect the population of Bihar, in particular children under the age of five years. The current sanitation paradigm treats human excreta as a waste product that remains unused or has to be removed from wastewater in order to avoid pollution of the environment. Using large amounts of water to flush toilets and treating wastewater from drop-and-discharge type of toilets is difficult in a increasingly water scarce environment and a developing country context. A new paradigm views sanitation of excreta as one part of a closed cycle in which the nutrients contained in excreta are reused in agriculture for food production. Megh Pyne Abhiyan (MPA) is a local Non Governmental Organization promoting ecosanitation that is particularly suitable for flood prone areas in North Bihar. The purpose of the present study was to investigate the sustainability of the ecological sanitation (ecosan) units promoted and implemented by MPA. Three districts in North Bihar were visited (Paschim (West) Champaran, Saharsa, and Khagaria). The assessment was based on four dimensions of sustainability following the SATNET Asia analytical framework and the technology was analyzed from a social, technical, economic and environmental point of view. Expert interviews, a questionnaire based household survey, focus group discussions, and direct personal observation of the physical ecosan units were used as research methods to collect data on selected sustainability criteria. A composite sustainability index (CSI) was calculated. Ecosan units can be considered a sustainable technology suitable for poor and vulnerable people. Ecosanitation is characterized by positive results regarding water and energy use, the technology's impact on biological processes and on biodiversity, the little land area required, and a low work load. Ecosanitation scores less compared to vermitechnology in terms of the risk of creating social conflicts or rejection in the neighbourhood, the share of female adopters using ecosanitation and in terms of the economic output. Respondents stated that the adoption of the ecosan unit saves time and reduces the amount of mineral fertilizer they have to purchase, hence reducing costs for crop production and liberating productive labour for other tasks. Future research should monitor and evaluate the agronomic and socioeconomic outcomes of the adoption of ecological sanitation in North Bihar.

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8. Annex

8.1. Survey questionnaire for adopter interviews

Ecological Sanitation in North Bihar (Questionnaire):

0.0 General

0.1 Village location

	Paschim (West) Champaran		**Khagaria**		**Saharsa**

0.2 Date of survey …………/……………/2013

0.3 Household Number …………………………………

0.4 Gender of respondent……….Male/Female *(If original M/F respondent not present, M/F figure interviewed………………………………….)*

1.0 Demographic

1.1 How many adults and children belong to this household? Women (16+)…………… Men (16+)................. Children male (1-15)……… Children female (1- 15) ……. Infants (under 1 year)…….**= Total**…………………..

2.0 Technical

2.1 Who introduced "Phaydemad Shauchalay" in your village, please specify? (1 = NGO …………………………, 2 = Government……………………, 3 = Person from village……………………., 4 = other ....……………..…………)

2.2 Year and month for construction of "Phaydemad Shauchalay" started. ……./………/……….

2.3 How long did it take you to decide to adopt the "Phaydemad Shauchalay" from the first time you heard about it/saw it?..

2.31 If it took more than a month for adoption, why?..
……………………………………………………………………………………………………
………………………………………………

2.4 How many paid workers built your "Phaydemad Shauchalay"?..

2.41 How many days on average did they work?...

2.42 How much were they paid/day?...

2.5 How many people volunteered to help build the "PhaydemadShauchalay"?...

2.51 How many days on average did they volunteer?...

2.6 How much did the sub-structure materials of the "PhaydemadShauchalay" cost (in rupees)?

	Cement	**Bricks**	**Iron rods**	**Pan**	**Pipes**	**Tap**	**Bamboo**	**…………………………………………**
Cost (in rupees)								

2.7 Which materials will be used in super structure of the "PhaydemadShauchalay"?

	Cement	**Bricks**	**Nails**	**Iron rods**	**Bamboo**	**Plastic**	**Thatch roof/tin roof (circle)**	**……………… …….**
Cost (in rupees)								

2.8 Were all the construction materials easily available in terms of time and transport? (1 = YES, 2 = NO)

2.81 If NO, which were a source of problem, and why? (please list and explain)…………………………………
……………………………………………………………………………………………………

……
………………………………………………………………………………………………….

2.9 What is the expected date for the "PhaydemadShauchalay" to be built? (days/weeks/months)…………..

2.10 What was difficult for you when building the "PhaydemadShauchalay"? …………………………………………….
……
…………………………………………………

2.11 What will be the difficult for you when you will start using the "PhaydemadShauchalay"?
....
…………………………………………………………...

2.12 What will you add in the "PhaydemadShauchalay" after defecating? (Circle answer)

Ash	Saw dust	Neem powder	Dried leaves	Soil	Grain husk	Water	Other (………………………)

2.13 Will you protect "PhaydemadShauchalay" from flood during monsoon? (1 = YES, 2 = NO)

2.131 If YES, what will you do to prevent it? Please explain……………………………………………………………..
…………………………………………………………………..

2.14 Have you innovated the "PhaydemadShauchalay" in any way? (1 = YES, 2 = NO)

2.141 If YES, in what way?...
…………………………………………………………………………………………………
………………………………………........

2.15 If you were to build the "PhaydemadShauchalay" again, would you build it differently, in a different location? Please explain…………………………………………………………………………………………………
……………………
……
……
………………………………………………………………………………………………….

2.16 I would like to see your "PhaydemadShauchalay", could you be as kind as to give me a visit? I would like to take the measurements and pictures of the "PhaydemadShauchalay". Do you agree that the pictures I take are published on the internet? You can review the pictures I take, and agree if they are alright to be placed online.

3.0 Social

3.1 Which class did you finish at school?……………………………………………………………………………………......
.

3.2 Do you use any "PhaydemadShauchalay"? (1 = YES, 2 = NO)

3.3 Will you own the "PhaydemadShauchalay"? (1 = YES, 2 = NO)

3.4 Is everyone in the household going to use the "PhaydemadShauchalay"? (1 = YES, 2 = NO)

3.41 If NO, who will not using the toilet?………………………………………………………………………………….

3.42 Why are they will not use the toilet?...

3.5 Will there be anyone in your household feel difficulties using the "PhaydemadShauchalay"? (1 = YES, 2 = NO)

3.51 Who?...
....

3.52 Why?...
....

3.6 Will you allow neighbours to use your "PhaydemadShauchalay" on a regular basis? (1 = YES, 2 = NO)

3.61 If NO, why?……….
…….

3.7 Have neighbours complained about the "PhaydemadShauchalay" since you started constructing it? (1=YES,2 =NO)

3.71 If YES, for what reason?
………
…….

3.8 Will you allow visitors to use your "PhaydemadShauchalay" on an occasional basis? (1 = YES, 2 = NO)

3.81 If NO, why?..........…….
…….

3.9 How many people will use your "PhaydemadShauchalay"?………………………………………………………………..

3.10 Do you wash your hands after urinating? (1=never;2=rarely;3=half the time;4=very often;5 = always).

3.101 If previous answer 1,2,3 or 4 why not always?...
....

3.11 Do you wash your hands after defecating?(1=never;2=rarely;3=half the time;4=very often;5 = always).

3.111 If previous answer 1,2,3 or 4 why not always?...
…….

3.12 Do you wash your hands before eating? (1=never;2=rarely;3=half the time;4=very often;5 = always).

3.121 If previous answer 1,2,3 or 4 why not always?...
....

3.13 Where will you wash hands after going to "Phaydemad Shauchalay"?..

3.131 Will there be soap available? (1 = YES, 2 = NO)

3.14 Will there be a door in the "PhaydemadShauchalay"? (1 = YES, 2 = NO)

3.141 What will it be made off?..

3.15 Can the "PhaydemadShauchalay" be locked from the outside? (1 = YES, 2 = NO)

3.16 Can the "PhaydemadShauchalay" be locked from the inside? (1 = YES, 2 = NO)

3.17 Where do you shower?...

3.18 How long*(In minutes, going and coming back?)* does it take you to get drinking water? ....

3.19 Do you use the same water for drinking and cooking/washing? (1 = YES, 2 = NO)

3.191 If NO, where do you get the other (……………………..) water from?..

3.192 How long*(In minutes, going and coming back?)* does it take you to get one supply of the other water?...

3.20 Who gets water most of the time?..

3.21 Water can transport parasites, which can lead to certain types of infections and diseases. Do you treat water you use as drinking water in any way?

	Boil	**Filter**	**Do nothing**	**Other (………………………………………………….)**
Treatment				

3.22 Have you tried to persuade others to adopt the "PhaydemadShauchalay"? (1 = YES, 2 = NO)

3.221 If YES, who?...

3.222 What was their response?...

3.223 Did they adopt the "PhaydemadShauchalay"? (1 = YES, 2 = NO)

3.23 Who will be in charge of cleaning the "Phaydemad Shauchalay"?..

3.231 How was this decided?..

3.24 Were you taught how to use and clean the "PhaydemadShauchalay"? (1 = YES, 2 = NO)

3.241 If YES, when?...

3.25 Who is in charge of emptying the urine basket?...

3.26 Where do you now go to toilet?...

3.261 How far is this *(In minutes, going and coming back?)*from the household?...........................

3.262 When do you use to go to this toilet (*e.g. before sunrise, afternoon, after sunset, etc.)*?.......
…………………………………………………………………………………..................................
....

3.263 Do you feel safe going there? (1 = YES, 2 = NO)

3.27 With "PhaydemadShauchalay", when will you go to the toilet?...
……………...
....

3.271 Will you feel safe going there? (1 = YES, 2 = NO)

3.28 Do you perceive handling of urine (1=YES,2=NO), and of humanure (1=YES,2=NO) as being disgusting?

3.29 Do others perceive your handling of urine (1=YES, 2=NO) and of humanure(1=YES, 2=NO) as disgusting?

4.0 Health and environment

4.1 Do you check the faeces of your children for infections (e.g. parasites, diarrhoea, worms, blood)? (1 = YES, 2 = NO)

4.11 If YES, what do you do if you identify an infection?..

4.2 Do you apply night soil (fresh excreta) to your crops/trees? (1 = YES, 2 = NO)

4.21 If YES, which crops/trees?..

4.3 Do you think there is a risk that night soil applied to certain crops can lead to infections in those consuming the crops? (1 = YES, 2 = NO)

4.31 Please explain your answer……….
…….

5.0 Economic

5.1 Do you own the land where your house is built? (1 = YES, 2 = NO)
5.2 Do you own the land where the "PhaydemadShauchalay" is being built? (1 = YES, 2 = NO)
5.21 If YES, did you have to buy that land to build the "PhaydemadShauchalay"? (1 = YES, 2 = NO)
5.3 How much are you willing to pay (in rupees) for land to build the "PhaydemadShauchalay"?................
………………………...
5.4 What portion of the money (in rupees) is being used to pay for the "PhaydemadShauchalay" came from where? *(Fill all the appropriate boxes*).

	Own savings	Bank	Government	NGO	Other (please specify
Amount (in rupees)					

5.41 If answer**Own savings**, do you consider building/buying "PhaydemadShauchalay" will be a good investment? (1 = YES, 2 = NO)*(economic and social perspective)*
5.411 Please explain why?...
……………………………………………………………………………………………
…………………………….................

5.5 Do you perceive the costs for "PhaydemadShauchalay" are:(One choice possible, tick appropriate)

	Extremely cheap	Cheap	Acceptable	Expensive	Extremely expensive
Costs					

6.0 Food and agriculture

6.1 Who is in charge of cooking meals?...
6.2 What do you use for cooking? (1 = coal, 2 = Wood, 3 = Cow dung, 4 = Gas, 5 = other (specify……........))
6.3 Will you have to think about producing enough ash for the "PhaydemadShauchalay"? (1 = YES, 2 = NO)
6.4 Where do you get food and water goodsfrom (tick appropriate) *(show respondents the table).*

	Own garden (own produce)	Market (buy)	River	Hand pump	Rainwater	Other …………………
Vegetables						
Fruits						
Meat						
Fish						
Drinking water						
Water for other uses						
Eggs						
Milk						

6.41 Do floods force you to get and buy food produce from different sources? (1 = YES, 2 = NO)

6.5 Explain the process that takes place from passing urine the "PhaydemadShauchalay" to applying it to the crops? *(Collection, storage, application)*
……………………………………………………………………………………
…………………………………………………..…………………………………………………………
……………………………………………….

6.6 Do you use fertilizers for your crops? (1 = YES, 2 = NO)

6.61 If YES, list the fertilizers you use for your crops……………………....……………………………….……..
……………………………………………………………………………………………………
………………………………………….....

6.7 If YES, please give estimated values for yearly costs *(one choice per fertilizer possible, those that do not apply, can be left blank):*

	OWN	**2000 rupees**	**4000 rupees**	**6000 rupees**	**8000 rupees**	**10,000 rupees**	**More than 10,000 rupees**
Chemical fertilizers							
Cow manure							
Cow urine							
Other…………………………………………..							

6.8 Do you use human urine to fertilize your fields? (1 = YES, 2 = NO)

6.81 If YES, do you add water to the human urine? (1 = YES, 2 = NO)

6.811 If YES, in what proportions?...

6.9 How do you apply human urine to your crops?...

6.10 What crops do you apply human urine to? (circle appropriate in the table below **Q 6.1111**)

6.101 Do you apply the same amount of human urine to all crops? (1 = YES, 2 = NO)

6.1011 If NO, to what crops do you apply less human urine? (L = LESS, M = MORE)

	Maize	**Sugar cane**	**Parval**	**Paddy**	**Onion**	**Bitter Gourd**	**Gourd**	**Chillies**	**Potatoes**	**……….….**
Urine applied										

6.11 Are there crops you do not apply human urine to? (1 = YES, 2 = NO)

6.111 If YES, which crops and why?..
…………………………………………………………………………………………………........
....

6.12 Do you have/ will have enough human urine for all your crops? (1 = YES, 2 = NO)

6.121 If NO, do you buy it from anyone else? (1 = YES, 2 = NO)

6.1211 If YES, from who, where?...

6.13 At what price is human urine sold and bought?
BUY……………………………………………………………………….....SELL.............................
....

6.14 Do you use your own humanure (composted excreta) for farming? (1 = YES, 2 = NO)

6.141 If NO, will you use it for farming in the future? (1 = YES, 2 = NO)

6.142 If YES, which crops?
……………………………………………………………………………………………………
………..

6.15 Do you buy humanure from other people as fertilizer? (1 = YES, 2 = NO)

6.151 If NO, why?...

……
………………………………….……………..

6.16 At what price are you willing to buy and sell a full bucket of "PhaydemadShauchalay" humanure? *(Show the respondent the bucket and ask them this question)*
BUY:………………………………………………………………………SELL:……………………
…………………………………………..

6.17 What criteria do you have for assessing urine's quality?
Good signs:……………………………………………………………………………………………………
………………………………....

Bad signs:……………………………………………………………………………………….…………
………………………………….

6.18 Do you buy less fertilizer since adopting the Urine Harvesting? (1 = YES, 2 = NO)

6.181 If YES, how much money on average do you save per year?..
……………………………………………………………………………………………............
....

6.182 What have you used this extra money for?...
……
…………………………………………..

6.19 Do you observe a change in yield of your crops since starting to apply urine/humanure?(1=YES,2=NO)

6.191 If YES, how did you observe this?...

6.20 How big is your cultivated area? *(Value in acres)*
……………………………………………………………………………………

6.21 After adopting the "PhaydemadShauchalay" do you feel you will have more time to do other things, because you don´t have to walk to the fields/forest to go to the toilet? (1 = YES, 2 = NO)

6.211 If YES, what are you able to do now, which you were not able to do before? Please explain.....
……
………………………………………………