Center for
Development Research
University of Bonn

Working Paper 168

Maksud Bekchanov and Pablo Evia

Resources Recovery ŀƴŘ wŜdzǎŜ ƛƴ {ŀƴƛǘŀǘƛƻƴ ŀƴŘ ² ŀǎǘŜǿŀǘŜǊ {ȅǎǘŜƳǎ hLJǘƛƻƴǎ ŀƴŘ LƴǾŜǎǘƳŜƴǘ /ƭƛƳŀǘŜ in South and Southeast Asiaƴ /ƻdzƴǘNJƛŜǎ

ISSN 1864-6638 Bonn, June 2018

ZEF Working Paper Series, ISSN 1864-6638
Center for Development Research, University of Bonn
Editors: Christian Borgemeister, Joachim von Braun, Manfred Denich, Till Stellmacher and Eva Youkhana

Authors' addresses

Dr. Maksud Bekchanov
Center for Development Research (ZEF), University of Bonn,
Genscherallee 3
53113 Bonn, Germany
Tel. 0049 (0)228-73 18 41; Fax 0049 (0)228-73 19 72
E-mail: mbekchan@uni-bonn.de
www.zef.de

Pablo Evia
Center for Development Research (ZEF), University of Bonn,
Genscherallee 3
53113 Bonn, Germany
Tel. 0049 (0)228-73 49 62; Fax 0049 (0)228-73 19 72
E-mail: pablo.evia@uni-bonn.de
www.zef.de

Resources Recovery and Reuse in Sanitation and Wastewater Systems

Options and Investment Climate in Selected South and Southeast Asian Countries

Maksud Bekchanov and Pablo Evia

Acknowledgement

This study was funded by Federal Ministry for Economic Cooperation and Development of Germany (BMZ) through a joint research project of International Water Management Institute (IWMI) and Center for Development Research (ZEF) titled "Research and capacity building for inter-sectorial private sector involvement for soil rehabilitation". The authors are very thankful to Professor Joachim von Braun for invaluable feedback to improve the paper.

Abstract

Properly managed sanitation systems and improved wastewater treatment are important for safeguarding environment and enhancing sustainable livelihoods in vast areas of South and Southeast Asian countries. Recovering nutrients and energy from organic waste and wastewater is an effective option for improving environmental and health security, rehabilitating agricultural soils and improving energy and food access for the poor in these countries. This study addressed the technical potentials and investment climate for wider adoption of resources recovery and reuse (RRR) technologies in this region. Reviewing results and technical calculations indicated poor sanitation in India and Nepal in contrast to high levels of sanitation in Sri Lanka. However, despite comparatively higher levels of fecal sludge and wastewater treatment in Sri Lanka than the remaining countries, levels of waste treatment and recycling are much lower than their potential level in all countries of the region. Lack of financial resources, lack of awareness on hazardous impacts of poor sanitation, poor governance and high corruption levels in the system are pointed out as key barriers for wider implementation of waste and wastewater treatment and recycling technologies. Improving regulatory frameworks and governmental support through establishing subsidy programs, raising the awareness of population on environmental safeguarding, improving the skill capacity and technologies as well as ensuring quality standards can enhance wider implementation of RRR options.

Keywords: composting, biogas, nutrient management, organic waste, wastewater, onsite sanitation, soil rehabilitation, governance, institutional framework

JEL codes: O13, Q53, O44, Q42, D02

Table of Contents

1 Introduction

Poor sanitation and mismanagement of waste under conditions of rapid urbanization are one of the key drivers behind many environmental and human health degradation problems across the developing world (Hutton et al. 2007; UN-HABITAT, 2010; Corcoran et al. 2010; Cairns-Smith et al. 2014; WWAF, 2017; UNEP, 2017). Therefore, improving the governance and infrastructure in the waste and wastewater management sector is essential for better environmental systems and sustainable livelihoods. In addition to improved environment and health impacts, proper handling and recycling waste may turn the waste into asset which can augment water, energy and nutrients supply (UN-WATER, 2016; Strande et al., 2014; UN, 2016; Bekchanov, 2017a). Despite enormous costs of recovering nutrients, producing energy and treated effluents from waste and wastewater streams, the Resources Recovery and Reuse (RRR) options can be feasible under conditions of decreasing stocks of non-renewable minerals (phosphate rocks) and fossil fuels, and increasing water scarcity (Cordel et al., 2011; Höök and Tang, 2013; Lazarova et al., 2013).

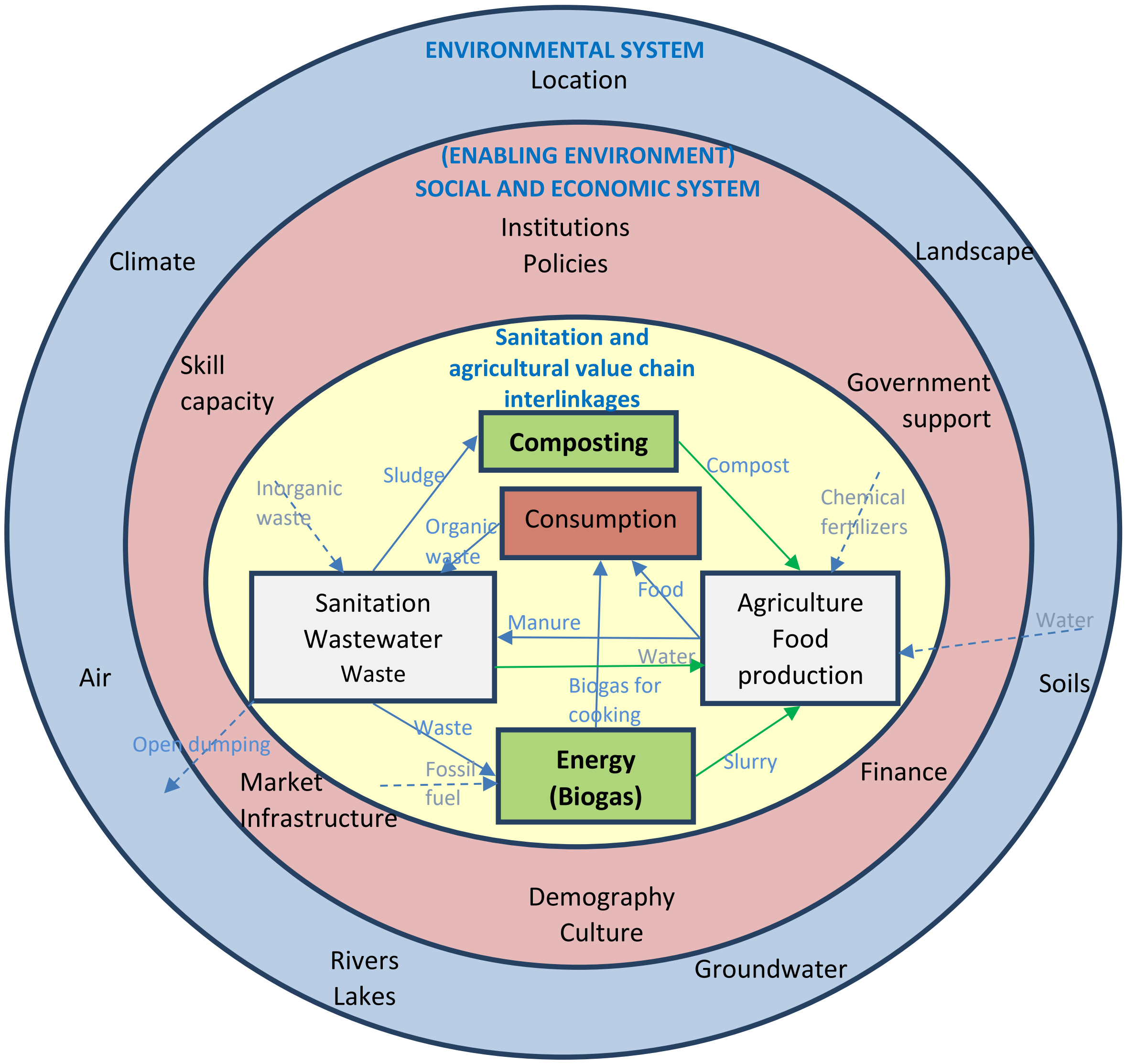
Nowhere is mismanagement of waste and wastewater systems more evident than in South and Southeast Asia. Lack of proper sanitation facilitates and unsafe disposal of waste and wastewater are common problems causing environmental pollution in many parts of this region (Visvanathan and Glawe, 2006). RRR options are highly relevant to enhance sustainable production and prevention of environmental degradation under these circumstances. This study thus aims at reviewing the current status of sanitation and wastewater management systems, and assessing the investment climate for introducing waste recycling options to enhance the sustainable livelihoods in the region. South and Southeast Asian countries considered under the study are India, Sri Lanka, Nepal, Bangladesh, Laos and Myanmar.

Next section presents briefly a conceptual-methodological framework of the study. It is followed by a section on the location and population in the studied countries. Next the current conditions of fecal sludge and wastewater management in these countries are analyzed. After that, RRR options currently applied to manage waste and wastewater are presented. Then, investment opportunities for wider implementation of waste treatment and recycling technologies are discussed. Particularly, affordability of RRR, demand for products produced through recycling, infrastructure, and regulatory and institutional frameworks are considered. The last section summarizes the findings and concludes.

2 Conceptual-methodological framework

Interlinkages between waste management and agricultural value chains and their relationship to general socio-economic framework and environmental system are considered in the conceptual framework presented in Fig. 1. The conceptual framework builds on the previous approaches to business climate assessment developed by World Bank (2015, 2017a), FAO (2013) and EAWAG (Strande et al., 2014). According to the framework, waste management and agricultural value chains as part of a broader economic system is influenced by general socio-economic and institutional conditions (Hasan 2018). The value chains and the socio-economic system functions within the physical environment which plays a pivotal role for the sustainability of the production system and determines the relevance of the production and recycling technologies to a particular location.

Figure 1: Waste management and agricultural production value chains as part of a broader socio-economic, institutional and environmental system



Source: Authors' presentation

The micro environment depicts the specifics of sanitation and agricultural value chains and their interlinkages. If composting and biogas production from organic waste or safe disposal of waste are underdeveloped, large portion of the generated waste ends up in waterways, lakes, and neighboring areas, polluting water sources, causing toxic gas emissions and damaging environmental health. RRR options such as compost and biogas production from organic waste greatly help in reducing the amount of waste to be openly dumped and supply additional energy or fertilizer for production processes and household consumption.

Understanding the interlinkages between sanitation and agricultural value chains is essential to assess the amount and value added of input and output flows along the chains concurrently determining any issues related with input supply, high costs, low productivity, demand and competition for the outputs. For instance, aiming at introducing composting technologies may not yield the expected results due to lack of proper sanitation and waste collection facilities. Or, in water abundant conditions characterized with heavy rainfall, a reuse of treated wastewater is less likely to be an economically viable option. Likewise, if the costs of chemical fertilizers are much cheaper than producing and applying compost in crop production, promoting demand for compost cannot be easy. Similarly, biogas plants may not be preferred by households and businesses if cheap electricity or gas is available as an energy source.

In addition to production system characteristics, the consideration of geographic conditions is essential for assessing the relevance of any RRR option for particular location. Groundwater levels influence on the choice of sanitation facility, for instance. Fertilizer application requirements may vary depending on soil type and thus it may determine overall compost demand in particular area. Cold temperature may reduce the technical and economic feasibility of biogas plants. Since compost plants require large area and may cause unpleasant odor in the neighborhood this option can be less recommendable in densely populated areas.

Except technological and environmental conditions, socio-economic and institutional factors also play an important role for the choice of appropriate RRR option. Lack of proper laws, policies and institutions to incentivize the implementation of improved sanitation and RRR options may lead the continuation of unsustainable waste management practices and environmental degradation. Even if proper laws for safeguarding environment exist, enforcement of these laws and monitoring can be limited. High corruption levels and lack of transparency are key barriers for maintaining the rule of law. In case the laws are supportive to enhance sustainable production and adoption of RRR options, financial feasibility of such changes may depend on income levels of people, access to credit, and subsidization rates. Infrastructural conditions such as access to energy, water, roads, education services, and information and communication technologies (ICT) are also important for the feasibility of RRR options. Availability of affordable technologies (mechanized compost application) and skilled workers are required for the continuation of the RRR processes. Socio-cultural factors play an important role for wider implementation of RRR options. For instance, the use of fecal sludge for biogas generation and biogas use for cooking can be unacceptable in some societies because of social stigma attached to excreta.

Based on this conceptual framework, this study systematically collects data related to processes along the sanitation, waste management and recovered commodity value chains. The study also considered socio-economic and institutional factors determining the enabling environment for RRR options and physical - environmental conditions across the studies South and Southeast Asian countries.

Technological processes along waste management and agricultural value chains are depicted based on technical documents prepared by experts and researchers. Data on natural conditions are mostly collected from the reports of statistical and environmental agencies of the respective countries. Socio-economic and institutional factors (enabling environment) are evaluated based on expert survey analysis results and the database of the World Bank on World Development Indicators. Additionally, information was obtained from the research reports of other international organizations such as Asian Development Bank (ADB), International Centre for Integrated Mountain Development (ICIMOD) and Japan International Cooperation Agency (JICA).

3 Study area – location and population of South and Southeast Asia

South and Southeast Asia region is bordered on Middle East in Northwest and China in Northeast (Figure 1). Among South Asian countries, India is the largest with a territory of about 3.3 million km^2. An island country – Sri Lanka is the smallest with the territory of 65.5 thousand km^2. Despite their different sizes population densities are similar in these two countries (338 and 445 people per km^2 respectively; Table 1). Bangladesh is the most densely populated (1,250 people per km^2) among the studied countries while population density is very low in Laos and Myanmar.

Total population in the South Asian countries under this study are 1.6 billion which accounts for 21% of global population (Table 1). India with population of over 1.3 million is the most populous country in South Asia and the second most populous in the world (after China). Over 160 million people reside in Bangladesh while Laos has only 6.8 million population despite its larger territory. More than 80% of population lives in rural areas in Nepal and Sri Lanka. In the remaining countries, people residing in rural areas exceed 60%. Taking into account the average global proportion of rural population (45%), the relatively higher proportion of rural population in the studied countries could represent a need for decentralized sanitation facilities and an opportunity to implement RRR technologies in order to decrease environmental and health hazards.

Figure 1: Map of South and Southeast Asia

Country	Area (sq. km)
Bangladesh	147,630
India	3,287,259
Laos	236,800
Myanmar	676,590
Nepal	147,180
Sri Lanka	65,610

Source: Google maps

Table 1: Population (2016)

Country	Population (million people)			%		Population density
	Total	Urban	Rural	Urban	Rural	People per sq. km
Bangladesh	163.0	57.1	105.9	35.0	65.0	1,252
India	1,324.2	438.8	885.4	33.1	66.9	445
Laos	6.8	2.7	4.1	39.7	60.3	29
Myanmar	52.9	18.3	34.6	34.7	65.3	81
Nepal	29.0	5.5	23.5	19.0	81.0	202
Sri Lanka	21.2	3.9	17.3	18.4	81.6	338
Total	1.597.1	526.3	1070.8	32.9	62.1	

Source: Based on World Bank (2017b)

4 Sanitation and wastewater management chain

Densely located population and lack of infrastructure for proper sanitation are behind the major environmental and water pollution problems in most countries of South and Southeast Asia. High rates of open defecation and essentially psychological preference for such behavior are key barriers for safe management of waste and implementation of RRR technologies. As shown in Table 2, in contrast to very low levels of open defecation in Bangladesh and Sri Lanka, open defecation rates are enormously high – reaching almost 40% - in India in spite of so many efforts to provide cheap toilets and improving the sanitation. High rates of open defecation and low sanitation access rates are also specific to Nepal and Laos. Higher prevalence of open defecation is strongly correlated with lower quality of drinking water and higher rates of diarrhea related morbidity and stunting in children (Vangani et al. 2016, Hasan 2018). Open defecation has spillover effects even on the households that use improved sanitation facilities as the children from these households face stunting issues similar to the children of neighboring households without access to improved sanitation (Vangani et al. 2016).

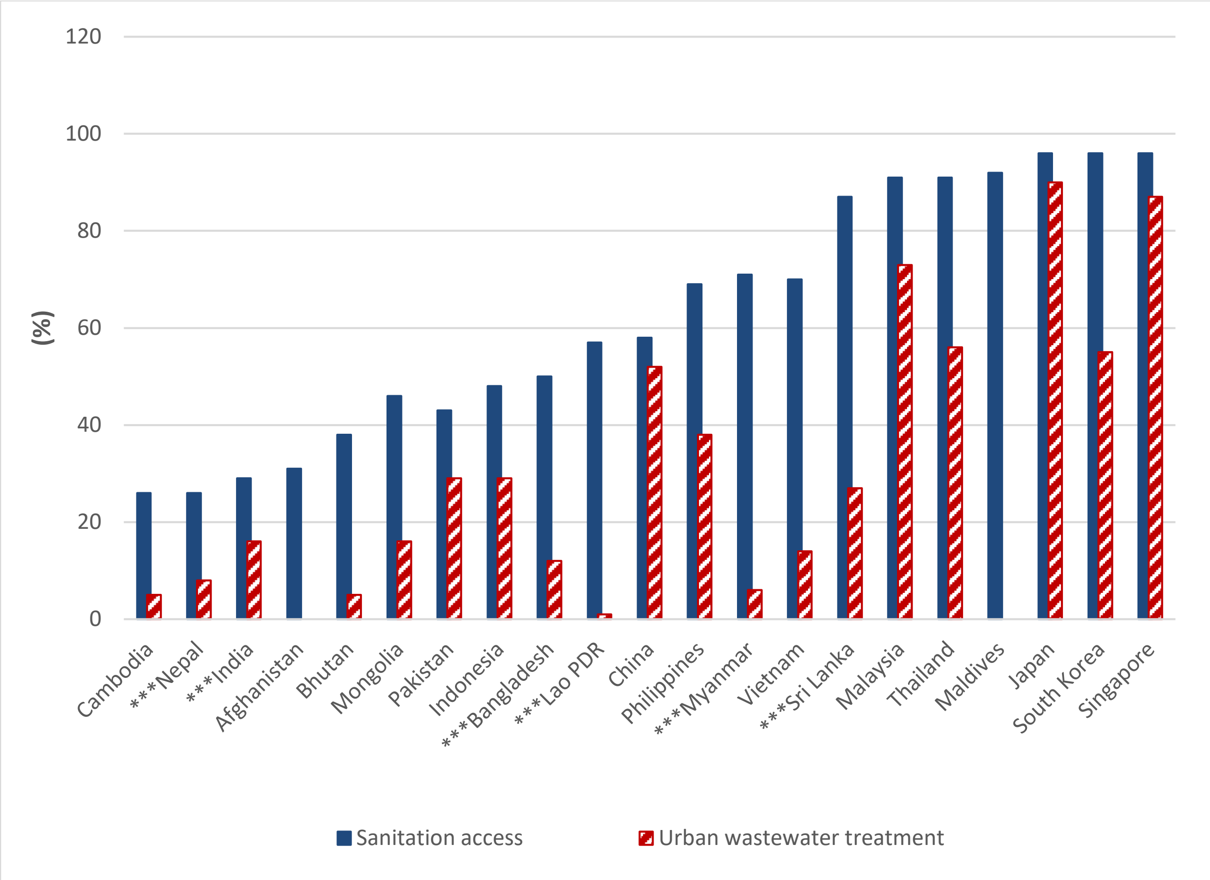
Table 2: Sanitation (2015)

Country	Access to sanitation	Open defecation rate
Bangladesh	60.6	0.1
India	39.6	39.8
Laos	70.9	22.1
Myanmar	79.6	4.7
Nepal	45.8	29.8
Sri Lanka	95.1	2.6

Source: Based on World Bank (2017b)

Fecal sludge and wastewater treatment levels in the South and Southeast Asian countries are quite low compared to the sanitation rates and the average wastewater treatment levels in other Asian countries with high income levels. Figure 2 illustrates the ranks of the studied countries among Asian countries according to access to sanitation (availability of sanitary toilets) and the level of wastewater treatment. According to UNEP (2017), sanitation access is quite low in Nepal and India and leveled at less than 30% though low wastewater treatment levels are comparable with Bangladesh. Bangladesh and Laos have similar sanitation access at levels of 50-60% but wastewater treatment almost lacks in Laos. Wastewater treatment levels are also quite low in neighboring Myanmar though sanitation rates are higher than 70% in this country. Sri Lanka performs best among the studied countries reaching high sanitation access comparable to in the developed countries of the region but wastewater treatment levels in urban areas are quite low compared to those in the developed countries.

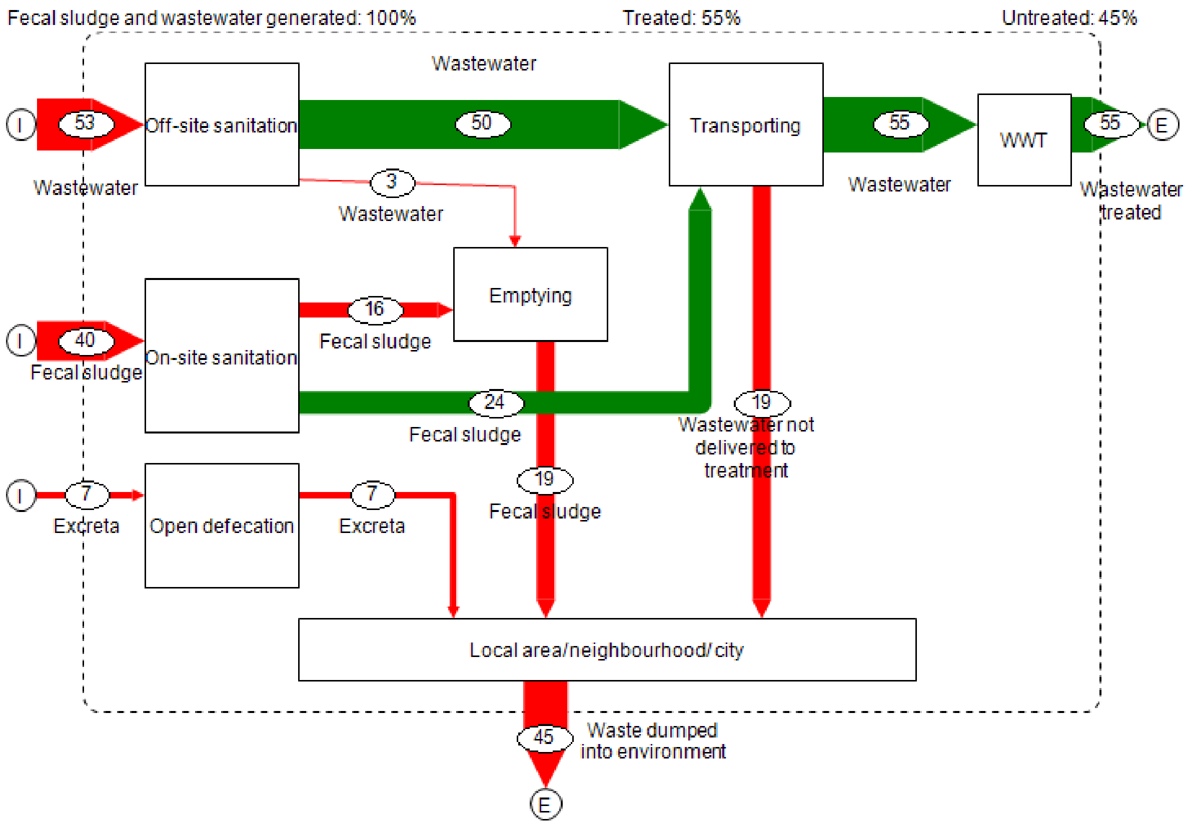
Figure 2: Access to sanitation by households and wastewater treatment levels across Asia



Source: Based on UNEP (2017)

Example of fecal sludge management in Tumkur city of India (located 70 km away from Bangalore – the capital of the state of Karnataka) was shown in Figure 3. Half of the population in the city is provided with sewerage system which conveys 50% of wastewater generated to treatment plants. Small portion of wastewater joins to drainage waters due to leakage or failure in the sewerage system. 19% of fecal sludge from on-site facilities is dumped directly into the drainage system. Despite 24% of the fecal sludge from the on-site facilities are collected only 5% of the sludge is treated and the rest is released into neighborhoods without a proper treatment. Open defecation rate is 7%. Overall, almost half of the wastewater and fecal sludge generated end up in open fields and drainage system without any prior treatment and thus contributes to heavy environmental pollution, groundwater contamination and spread of the diseases (Gunawan et al. 2015, Vangani et al. 2016).

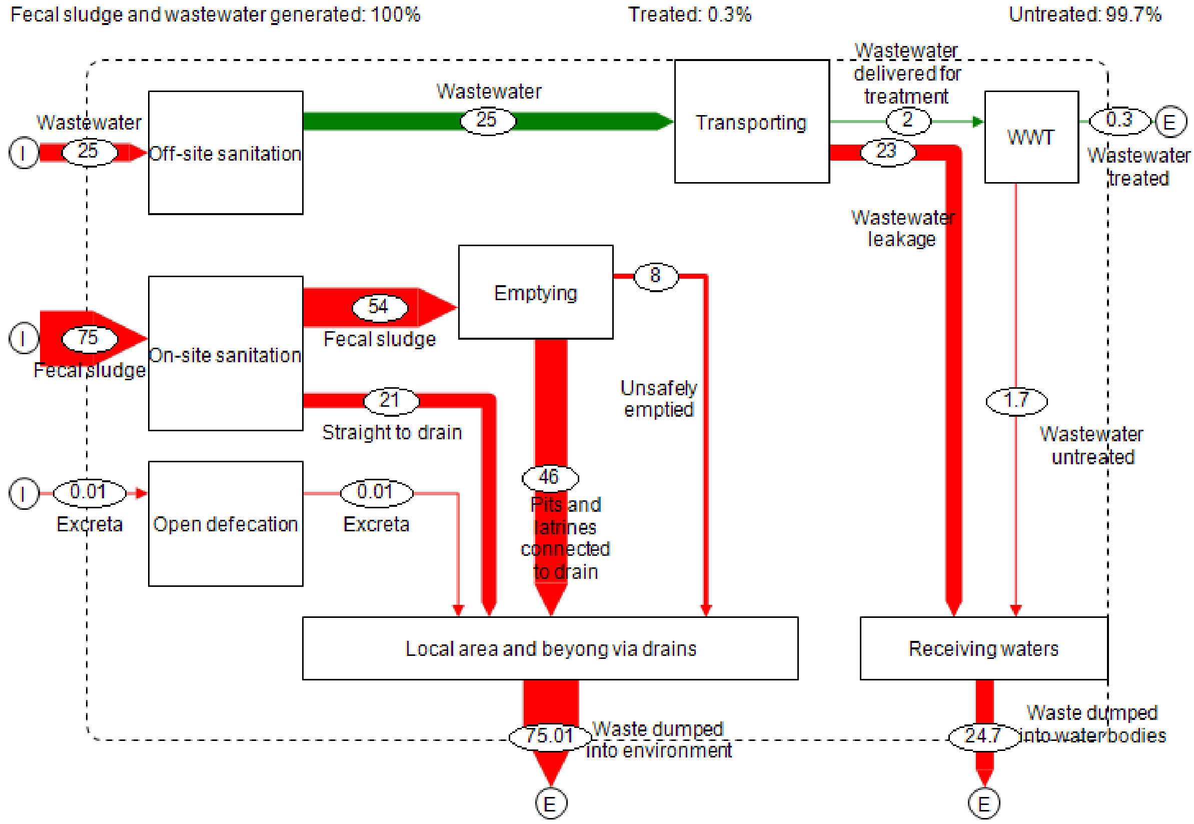
Figure 3: Fecal sludge and wastewater management in India (the case of Tumkur city)



Source: Based on Gunawan et al. (2015)

Although open defecation is not a big problem in Dakka, Bangladesh, and flush toilets are commonly used for collecting fecal sludge, only 0.3% of total wastewater and fecal sludge generated are treated (Figure 4). Most water from sewerage system (which serves only 25% of the city population) are leaked into water bodies. Large portion of fecal sludge is dumped into open drainage which conveys it beyond the local area and discharges into environment without a proper treatment (Opel et al., 2012). Mechanical empting on-site facilities such as pit latrine and septic tanks are rare and manual emptying characterized with high disease risks is common practice across the country. The situation in other cities, where sewerage system lacks and on-site fecal sludge collection facilities are commonly in use, is even worse than in the capital city. Thus, since surface and groundwater sources are often contaminated with chemical pollutants and pathogenic microorganisms such as *E. coli*, withdrawing water from untapped sources for drinking increases diarrhea incidents and causes stunting in children (Hasan and Gerber 2016). Households with irrigating areas are more likely to use water mixed with wastewater and fecal sludge consequently facing with diarrhea issues and income losses due to productive time lost (Hasan 2018).

Figure 4: Fecal sludge and wastewater management in Bangladesh (the case of Dakka)



Source: Based on World Bank (2016)

Water supply and sanitation is underdeveloped in urban areas and lacks in rural areas of Nepal. For instance, in the Kathmandu Valley it has been reported that only 40% of households are connected to the sewerage system (ICIMOD et al., 2007). Across the country, only 12% of households in municipal areas have an access to sewerage system (Shrestha, 1999). In municipal areas without connection to sewerage system, septic tanks and pit latrines are in common usage (HPCIDBC, 2011). Effluents from these septic tanks and pit latrines are discharged into drainage system or soak pits where they are gradually absorbed into soil. Although private companies or municipalities are in charge of cleaning of the septic tanks, the cleaning is rarely conducted in time. Consequently, these septic tanks are filled up easily, do not function properly and cause heavy air, water and soil pollution. If 370 million liters per day (MLD) of wastewater is generated in Nepal, only 5% of this volume can be treated since the overall capacity of wastewater treatment plants (WWTPs) is 37 MLD and only 50% of these plants are operational (Nyachhyon, 2006).

In Colombo, the capital of Sri Lanka, the sewerage network covers only some parts of the city and comprises 320 km of sewers, 18 pumping stations, and two long outfalls into the deep sea (ADB, 2015). Given the lack of pipe-borne sanitation infrastructure in many parts of the country, fecal sludge in some areas is collected by special trucks to deliver them into treatment plant (Figure 5). Wastewater is recycled through passing several ponds in wastewater treatment plants and treated water is safely disposed into a lagoon or sea. In some places like Rathmalana in the South of the Colombo Municipality, a very modern wastewater treatment plant functions using advanced computer technologies for monitoring and managing wastewater treatment process. Treated wastewater is safely released into the sea thus not polluting the coastal area. Sediments are dried several days before being delivered to a compost plant for co-composting together with organic waste (food waste, crop residues, etc.) or dumped into landfills. In some cases, dried sediments were supplied to cement production factories for burning in cement kilns (Maheshi et al., 2015). In the areas without adequate access to sanitation services, disposal of wastewater and sewage sludge without proper treatment is a key reason for eutrophication and the spread of diseases in inland water bodies and coastal areas. Increased eutrophication may also damage coral reefs in the coastal zone and negatively effect on fishing industry (Sunday Times, 09 April 2017). Improper management of solid waste, such as dumping waste into wetlands or constructing inefficient landfills close to fresh water streams, causes organic and chemical contamination of water bodies and leads to the consequent loss of aquatic species and human health degradation (Lagerblad, 2010).

In Laos, fecal sludge management is quite undeveloped as only 35% of fecal sludge generated is stored in septic tanks and various poorly maintained latrines are in use for containing the remaining excreta (Opel and Cheuasongkham, 2015). Although open defecation rate is 4% in urban areas and 70% of population uses some type of toilets, open defecation rates are 40% in rural areas in this country (WHO/UNICEF, 2014). Fecal sludge collected in septic tanks is accumulated over 1 to 5 years for further collection. Since public service for collecting fecal sludge is quite limited, fecal sludge collection are mostly conducted by private companies. Because of long distance to the official dumping site and expensiveness of discharging the collected waste into the dumping sites, the collected fecal sludge is mostly dumped into waterways and the ditches along the roadside (Opel and Cheuasongkham, 2015). No regulation, monitoring and control exist for the illegal dumping of fecal sludge. At present, some cheap wastewater treatment plants based on planted reed beds are under way of construction which can lessen the environmental burden of the illegal dumping at least in some parts of the capital city (The Laotian Times, 2018).

Figure 5: Delivering the fecal sludge to the wastewater treatment plant (Sri Lanka, 2017)

Source: Photo by Bekchanov

According to the official statistics, Myanmar is well equipped with sanitary means of disposing excreta (Zaw, n.d.). The Ministry of Health provides subsidies to construct latrines in rural areas (ADB, 2013). Thus, improved toilets are used by 80% of population in rural areas and 94% in urban areas (Zaw, n.d.). Majority of population uses pit latrines with slabs for excreta containment. However, only 3-4% of households are connected to centralized sewerage system. Even in main urban areas such as Yandong, only key business districts are equipped with the centralized sewerage system. Sanitation services are below acceptable levels in the remaining areas. In Yandong city, only 7% of wastewater generated is treated before its release into environment and activated sludge from the plant is used as soil amendment (Premakumara et al., 2017). The remaining waste is mostly discharged into storm water canals or open waterways without proper treatment. These water ways are often blocked due to heavy loading of suspended solids or mismanagement, increasing the health risks such as malaria and dengue. Poor governance, lack of data and planning, financial shortcomings are key barriers for constructing a proper urban sanitation facilities in the country.

5 RRR options for treating organic waste and wastewater

5.1 Overview of RRR options

Technologies of treating and recycling fecal sludge vary depending on the purpose of the treatment (Table 3). Some municipal areas of South and Southeast Asia are equipped with cheap options of wastewater treatment such as planted or unplanted drying beds. The application of the advanced wastewater treatment technologies are very limited. Although Reverse Osmosis (RO) technique is effective in wastewater treatment and has positive effects on drinking water quality, high costs of the technique prevent its wider implementation (Vangani et al. 2016). Incineration is also applied yet at limited level (mostly in metropolitan cities of India) because of high operation and investment cost requirements. Studies on cultivating fly larvae and deep row entrenchment were not found. Resource recovery and reuse technologies are quite underdeveloped in Myanmar and Laos but composting and biogas plants are more common practices which are supported by various governmental policies across Sri Lanka, India, Nepal, and Bangladesh. Thus, we mainly focused on composting and biogas generation options across these four countries in this section.

Table 3: Fecal sludge treatment objectives and technologies

Treatment objective	Treatment technology
Solid-liquid separation	Unplanted drying beds
	Planted drying beds
	Mechanical dewatering technologies
	Settling tanks
Sludge stabilization	Composting
	Anaerobic digestion (biogas)
	Fly larvae (Soldier Fly)
	Incineration
Nutrient management	Vermicomposting
	Deep row entrenchment
Pathogen inactivation	Lime treatment
	Ammonia treatment

Source: Based on Strande et al. (2014)

5.2 Composting

Compost is a dark colored matter rich in nutrients and thus useful for improving soil fertility. As estimated, overall composting potential from organic waste is about 4.3 million tons in India (Chandran, 2012). Windrow composting is main type of composting across the country. Initial plans for composting organic waste were implemented as early as 1970s and thus several semi-mechanical composting plants have been constructed in many states of India at that time. However, most of these plants were also shut down due to lack of spare parts for machinery which are mainly imported. Even a malicious fault in the machines could prevent the entire process given the unavailability of spare parts for quick fixation of the mechanical problem. Frequent shortcuts in electricity also interrupted the process. Mixed waste with high content of glass, metal and rubber also frequently clogged the pulvetizers (grinders). It was not possible or very difficult to continue the composting process in rainy seasons. Demand for the produced compost was also low because of very low quality and contamination with various hazardous material (Ahluwalia and Patel 2018).

Given the increased environmental consciousness and with the support of the government program, compost plants started to grow since 2008 and were constructed in many cities. Composting plants in Bangalore, Nashik and Pimpri can recycle 100, 300 and 500 tons of organic waste daily. However, contamination of the produced compost with heavy metals is dangerous for soil health and might have consequences in the long term. Especially, compost made from municipal organic waste may contain batteries, glass particles and other harmful materials due to poor segregation of waste. Consequently, demand for such low quality compost is quite low (Ahluwalia and Patel 2018). At present, 95 commercial compost plants exist across India and these plants can recycle about 2.4 million tons of organic waste per annum. Yet, only 14% of their capacity is used due to low demand for compost (Ahluwalia and Patel 2018).

Most of the farmers in Bangladesh produce compost in their premises based on traditional ways and apply it for vegetables production. However, the application of modern ways of composting including vermicomposting are very limited (Mamun-ur-Rashid, 2013). Large-scale composting plants are rare and mostly run by a few commercialized organizations such as Waste Concern, Annapurna Agro Service, Grameen Shakti and Rural Development Academy (Rashid, 2011). Although most farmers are less aware of the soil productivity enhancement properties of the compost, some farmers in rural areas of Bangladesh prefer using compost for reducing external environmental effects of chemical fertilizer application, improving soil structure, avoiding high expenditures for inorganic fertilizers, and ensuring safe disposal of organic waste. Crop residues, kitchen waste, dry leaves, hay, ashes, and manure are main types of organic waste for composting. Both men and women are widely involved in processing compost in rural areas across the country.

Composting organic waste is also limited in Nepal. There have been efforts to establish a composting plant in Kathmandu municipality in Nepal. GIZ supported and funded the construction of compost plant with an annual capacity of producing 30 tons of compost in Teku transfer station in Kathmandu (Dangi et al. 2013). However, the project was stopped by the municipal council citing to malodor, lack of market for composts, and the complaints about the low quality and glass hazards of compost. Instead, Kathmandu municipality provided 600 households (out of 150,000) with compost bins with a volume of 100 l, for promoting mini-scale composting.

It was reported that there was a single large-scale composting plant in Bhaktapur region of Kathmandu municipality before 2007 (ICIMOD et al., 2007). The plant received about three tons of waste per day. However, the composting in this plant was based on a simple methods and most operations are carried out manually. Other private initiatives to establish composting plants did not have much progress until the recent past since low priority was given for these programs (ICIMOD et al., 2007). At present, some NGO initiatives to raise awareness on recycling waste and not to pollute environment are there through international donor support[1]. Since 2014, Biocomp company also started running a composting plant in Khokana[2]. The composting process is largely mechanized and some positive signs of progress have been recognized. Rather than waste treatment and recycling, some initiations on safe disposal of waste became successful (Dangi et al., 2013). For instance, GIZ supported the construction of Gokarna landfill. JICA similarly financed the establishment of Sisdol landfill.

In many areas of Sri Lanka, composting at household level was supported by sharing composting bins by local governments or NGOs. Centralized composting, especially using windrow composting technology, is also becoming common. Following the Pilisaru Program adopted by the national government in 2008, over 110 compost plants were planned to be established (JICA 2006, Table 4). 94 composting plants out of 119 are under operation at present and 17 are under construction (Bekchanov, 2017b). In districts such as Kurunegala, Anuradapura, Polonnaruwa, and Badulla where agriculture is a backbone for rural livelihoods, the targeted rates of waste recycling are substantial.

[1] http://cleanupnepal.org.np/
[2] http://www.biocompnepal.com/

Some plant operations even faced to public protests over malodor and water pollution in some areas. Lack of technical skills to operate the plant, low quality of compost, and underdeveloped marketing system for compost also hinder successful performance of composting plants (Pandyaswargo and Premakumara, 2012).

Table 4: Municipal solid waste collection and composting rate across Sri Lanka

Provinces	**Districts**	**Waste collection (tons per day)**	**Number of compost plants**	**Targeted waste (tons per day)**	**Targeted waste (%)**
Northern	Jaffna	78.5	3	11	14.0
North-central	Anuradapura	64.7	14	46.5	71.9
	Polonnaruwa	17.5	2	12	68.6
	Total	160.7	19	69.5	154.5
Northwestern	Kurunegala	113	16	88	77.9
	Puttalam	87.9	5	30	34.1
	Total	200.9	21	118	58.7
Central	Kandy	209.5	4	17	8.1
	Matale	47.3	4	8	16.9
	Nuwara Eliya	58	2	5	8.6
	Total	314.8	0	30	9.5
Western	Colombo	1,284	2	7.3	0.6
	Kalutara	126.5	7	69	54.6
	Gampaha	372.5	8	40.5	10.9
	Total	1783	17	116.8	6.6
Southern	Hambantota	50	8	30	60
	Matara	92	7	51	55.4
	Galle	107.5	9	13	12.1
	Total	249.5	24	94	37.7
Sabaragamuwa	Kegalle	65.5	6	34	51.9
	Ratnapura	88	2	2	2.3
	Total	153.5	8	36	23.5
Uva	Badulla	75.6	5	52	68.8
	Monaragala	35	2	4	11.4
	Total	110.6	7	56	50.6
Eastern	Ampara	142.5	5	13	9.1
	Batticaloa	136	1	9	6.6
	Total	278.5	6	22	7.9
Sri Lanka	Overall	3,424	119	656.8	19.2

Source: Based on Central Environmental Authority

5.3 Biogas generation

Biogas production from organic waste is getting momentum across the world. China and India are the leaders in the implementation of the biogas technology (Halder et al., 2016). Promotion of biogas plants started since 1970s in India following the first global energy crisis which decreased energy access and its economic feasibility in rural areas (Deo et al., 1991). At present, about 5 million biogas plants have been constructed across the country (Mittal et al., 2018). As estimated, total potential of constructing biogas plants is about 12 million (CSO, 2014). Despite quite large number of biogas plants, the share of biogas in energy consumption of households is low and the dissemination rate of biogas plants is slow. Total amount of biogas generated currently at the level of 2.1 billion m^3 per annum is also quite low compared to its overall potential of 29-48 billion m^3 (Mittal et al., 2018). Recycling municipal organic waste using anaerobic technologies is currently quite low because of expensive investment requirements and low profitability of such options (Mittal et al., 2018). Biogas based power generation plants are rare and only 56 plants operate across the country. Most of these plants are located in Maharashtra, Kerala, and Karnataka states (CPCB, 2013). Production of briquettes (Refuse Derived Fuel – RDF) from organic waste for further use as fuel is limited due to high costs of production, and bulky mass of the fuel and the residual ash (Ahluwalia and Patel 2018).

In Bangladesh, Bangladesh Agricultural University constructed the first biogas plant in 1972 for research purposes. Several organizations such as Government Engineering Department, the Bangladesh Council of Scientific and Industrial Research, and the Infrastructure Developing Company Limited (IDCOL) became active in supporting the adoption of small-scale biogas digesters by households. At present, about 80,000 small-scale biogas digesters have been installed already across the country yet over 4 million biodigesters can be built to recycle the entire organic waste (Bahauddin et al., 2012). Thus, over 2.7 billion m^3 biogas which is equivalent to 1.5 tons kerosene can be produced just recycling the livestock manure. IDCOL financed also to construct several biogas based power generation plants. A plant established by Paragon Agro Ltd using the IDCOL funds, for instance, produces 2,400 m^3 biogas from litter and uses it for generating 3,840 kWh electricity daily (IDCOL, 2016).

The first biogas plant in Nepal was introduced by Father B.R. Saubolle in 1955 (Gautam et al. 2009) and several years were required to draw the attention of government officials for promoting biogas plants. Starting from 1975, the Nepal government offered interest free loans for biogas plant construction. Under the initiation of the Department of Agriculture, Gobar Gas Thata Agricultural Equipment Development Company (GGC) was established in 1977 and 250 biogas plants were built. In 1990, modified Chinese fixed-dome model of generating biogas has been accepted as a suitable model across Nepal. Given the expansion of biogas plant sector, Biogas Support Program (BSP) was established with the support and funding by the Netherland Development Organization (SNV) to develop the biogas sector in 1992. The BSP was realized in four phases and over 200,000 biogas plants were constructed across Nepal till 2010. Number of biogas plants constructed reached to almost 270,000 coming 2012 (Table 5). Biogas plants were installed mainly in households for recycling cattle and buffalo dung, and thus have small size (4-10 m^3). Biogas plant implementation took place in majority of districts across Nepal except some few northern districts where biogas generation is not efficient due to cold temperature (Table 5). Several environmental and health benefits of biogas use are encountered. Earlier agricultural residues and cattle dung cakes were used in inefficient cooking stoves, causing heavy indoor pollution and leading to increased incidents of respiratory system illnesses (Pandey, 1984). Biogas uses reduced smoke exposure in the indoor environments and thus reduced exposure to acute respiratory illnesses. Additionally, child mortality rates and eye ailments were reduced.

Table 5: Number of biogas plants constructed across Nepal (in 1992-2012)

Regions	Years 1992-1999	2000-2004	2005-2009	2010-2012	Total	Technical potential of biogas plant construction	Actual to potential ratio (%)
Remote Hill	153	427	584	278	1442	43,255	3.3
Hill	33,661	40,433	39,019	20,445	133,558	344,008	38.8
Terai	27,857	37,926	49,699	17,917	133,399	636,107	21.0
Total	61,671	78,786	89,302	38,640	268,399	1,023,370	26.2

Source: Based on BSP (2012)

In Sri Lanka, initial experimental projects of implementing aerobic digestion technology primarily aiming at energy recovery have been conducted in Kirulapone and Matale (UNEP 2001, Pandyaswargo and Premakumara 2012). Household biogas plants were also introduced in some regions (De Alwis, 2002). Despite failures due to low financial and technical feasibility in some cases, waste-to-biogas project became successful when implemented in hotels. Treated wastewater and compost through waste recycling were also effectively used for gardens in some hotels such as Jetwing Blue. More recently, researchers of Moratuwa demonstrated also waste-generated-biofuel for using in three-wheels (De Alwis, personal communication, 30.08.2017). At present, several commercial companies such as BIOGAS Ltd and BIOFUEL LANKA Ltd are engaged in installation of waste-to-biogas plants throughout the country. Incineration of waste is less common and can be operating only in few hospitals and industries. Unfortunately, incinerations are not equipped with emission control devices (UNEP, 2001). A wider adoption of incineration technology to treat municipal waste across the country is very limited because of a high share of organic matter, high moisture content and low calorific value of municipal waste. In case of Sri Lanka, the incineration may require supplementary fuel since the calorific value of waste in the country is 2 to 3 times lower than in developed countries where the incineration treatment of waste is commonly used.

6 Economy and financial capability

The adoption rates of improved sanitation facilities and RRR options are largely determined by financial capability and income levels. Thus, income levels and stability as reflected through GDP per capita, inflation rates and access to credit are discussed in this section.

Given its big territory and population size, India is also the most voluminous in terms of economy earning annually over US$ 8 trillion (Table 6). However, per capita income is the highest in Sri Lanka compared to the remaining countries of South Asia and reaches US$ 11,400. It is also noticeable that the inflation rate in Sri Lanka leveled at 3.7% is one of the smallest, reflecting a greater macroeconomic stability after the end of civil war in 2009. Bangladesh and Nepal are the poorest in terms of income per capita which are leveled at US$ 3,320 and 2,300 respectively.

Table 6: GDP and inflation rates (2016)

Country	GDP (US$ Billion)	GDP per capita (US$)	Inflation rate
Bangladesh	540.9	3,319.4	5.5
India	8,067.7	6,092.6	4.9
Laos	38.8	5,734.5	1.5
Myanmar	280.6	5,305.0	10.8
Nepal	66.6	2,297.7	7.9
Sri Lanka	242.1	11,417.3	3.7
TOTAL	**9,236.7**	**5,783.8**	**-**

Source: Based on World Bank (2017b)

Note: GDP figures are at constant prices for 2011. Inflation rates for Myanmar and Nepal are for 2015.

In addition to income levels, interest rates and access to credit is also essential for assessing financial viability of technology upgrading. Table 7 shows the interest rate for 2016 and the 'Easiness of getting credit' (EGC) index for 2018. Both measures are meant to reflect in some way the possibility of financing investment projects in each of the six economies studied. As shown, the cases of India and Nepal are the most notorious, as these economies reflect the highest EGC index and the lowest lending interest rate, respectively. Difficulty in obtaining credit in Myanmar and high interest rates in Laos are main problems related with financial viability of technological changes.

Table 7: Interest rates and Easiness of Getting Credit (EGC) index (2016)

Country	Interest rate (%)	Easiness of getting credit (EGC) index
Bangladesh	10.4	25
India	9.7	75
Laos	22.6	55
Myanmar	13.0	10
Nepal	8.0	50
Sri Lanka	11.7	40

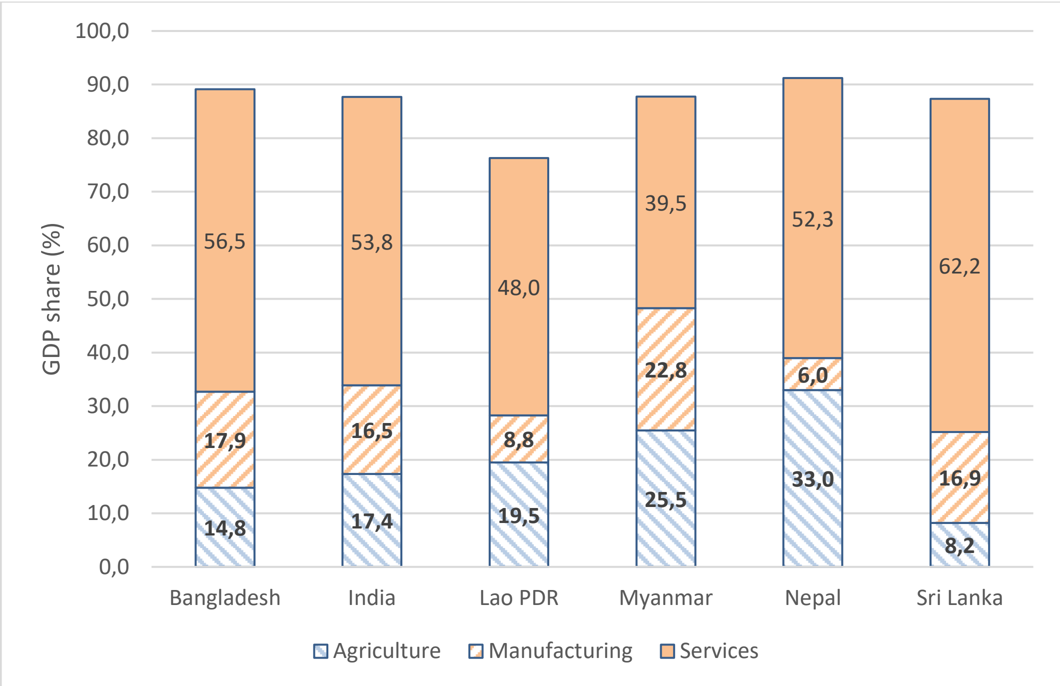
Source: Based on World Bank (2017b, 2018)

Note: Interest rates are average lending rates as of 2016. 'Easiness of getting credit' index is expressed as the 'Distance to the frontier' (DTF), i.e., a low score represents a more adverse scenario in terms of financing enterprises.

7 Agricultural production capacity and demand for fertilizer

Agriculture plays a pivotal role in the studied countries (Figure 6), implying a substantial demand for fertilizers which can be also met through nutrient recovery from organic waste streams. Agriculture contributes over 15% of GDP in India and Bangladesh but this sector accounts for more than 25% of GDP in Nepal and Myanmar. The smallest share of agriculture in GDP among the studied countries is 8% and for Sri Lanka. Nevertheless, agriculture dominates in rural areas and majority of the population resides in these areas. Thus, sustainability of agriculture and adequate supply of irrigation water and soil fertility are essential for food and income security in this region.

Figure 6: Sectorial structure of the national economies (2016)



Source: Based on World Bank (2017b)

Agricultural land areas are mostly used for producing cereals such as paddy rice in the studied countries (Table 8). Half of the croplands are irrigated in Bangladesh and only 10% in Laos. Given the high precipitation rates, rainfed agriculture dominates in most of the areas in the region. Forests cover 80% of total land area in Laos but only 10% of Bangladesh. Given the low population density, high precipitation and high forest coverage of the territory, expensive technologies for centralized fecal sludge recovery are less feasible in Laos and Myanmar (except in their central urbanized regions). Thus, perhaps only safe disposal of fecal sludge with less damage to human and environmental health or deep entrenchment for enhancing forestry can be an option for these countries. Given the high population density and extensive irrigated areas, adoption of nutrient technologies seems more important to Bangladesh and India but their economic feasibility should be further clarified.

Both nitrogen and phosphorus chemical fertilizers are largely imported in all South Asian countries considered (Table 9). India, for instance, imports over 4.8 million tons of nitrogen and produces 12.3 million tons domestically (as of 2014). Nepal and Sri Lanka solely depend on the imports of nitrogen fertilizers, while substantial portion of nitrogen uses is based on imports in Myanmar and Bangladesh. Phosphorus is also solely imported in all countries except India and Bangladesh (as of 2014). Even in Bangladesh, import of phosphorus is 7-8 times higher than its domestic production.

Table 8: Agricultural land uses in South and Southeast Asia (2014)

	Agricultural land (million ha)	**Cereals area (million ha)**	**Irrigated area (% of total cropland)**	**Forest area (% of total land area)**
Bangladesh	9.1	12.1	52.6	11.0
India	179.7	99.0	36.8	23.8
Laos	2.4	1.2	11.5	81.3
Myanmar	12.6	7.7	24.8	44.5
Nepal	4.1	3.5	29.7	25.4
Sri Lanka	2.7	1.0	n.a.	33.0

Source: Based on World Bank (2017b)

Demand for fertilizer is also increasing substantially in some South Asian countries (Table 9). For instance, phosphorus exports increased from 255 thousand to 454 thousand tons in Bangladesh during the period between 2010 and 2014. Similar rates of both phosphorus and nitrogen exports occurred in Sri Lanka at the same period. In Myanmar and Nepal, demand for fertilizers increased more than five times in the period between 2005 and 2014. Rapidly increasing demand for fertilizers in these countries indicate a large market potentials for the soil amendments and compost recovered from organic waste and wastewater.

Table 9: Domestic production, exports and imports of chemical fertilizers (tons)

		Nitrogen			**Phosphorus**		
	Year	**Production quantity in nutrients**	**Exports quantity in nutrients**	**Imports quantity in nutrients**	**Production quantity in nutrients**	**Exports quantity in nutrients**	**Imports quantity in nutrients**
Bangladesh	2005	880,646	179,962	292,643	69,022	0	257,691
	2010	491,520	40,916	716,206	50,140	0	245,946
	2014	394,580	0	881,420	61,640	0	454,480
India	2005	11,218,193	10,127	1,389,864	4,092,561	10,869	1,144,742
	2010	12,087,720	17,396	4,547,810	4,303,880	5,563	3,698,990
	2014	12,329,482	19,136	4,809,303	4,097,197	20,553	1,886,750
Laos	2005	0	0	0	0	0	0
	2010	0	0	0	0	0	0
	2014	0	0	0	0	0	0
Myanmar	2005	46,058	0	7,736	0	0	8,051
	2010	16,235	0	35,064	0	0	10,476
	2014	76,368	0	83,015	0	0	27,145
Nepal	2005	0	0	9,000	0	0	7,000
	2010	0	0	43,148	0	0	10,130
	2014	0	0	96,718	0	0	41,940
Sri Lanka	2005	0	0	159,595	11,042	0	22,639
	2010	0	0	166,096	10,000	0	40,679
	2014	0	0	227,403	1,000	0	45,403

Source: Based on FAO (2018), data was not found for Laos

8 Infrastructure

Access on specific public services such as safe water and electricity is essential for technical feasibility of waste and wastewater management and recycling technologies. Sri Lanka is very well equipped with potable water and electricity provision services (Table 10). Water and electricity is also high in India and Nepal. Electricity access is low in Bangladesh and Myanmar which means potential difficulties in mechanical operations related with waste treatment and recycling. The development of ICT, which is essential in marketing the RRR products and improve the relationship between producers and consumers, is quite low in Sri Lanka in contrast to India where ICT are quite well developed.

Table 10. Access to infrastructure (%, 2015)

Country	Access to water	Access to electricity	Information & communication technology index (0-9)
Bangladesh	86.9	62.4	4.5
India	94.1	79.2	6.0
Laos	75.7	78.1	2.5
Myanmar	80.6	52.0	4.5
Nepal	91.6	84.9	4.0
Sri Lanka	95.6	92.2	2.5

Source: Based on World Bank (2017b)

9 Governance and regulatory framework

Quality of public policies are important in order to carry forward entrepreneurship projects in general, and RRR projects in particular. In this sense, it is important to assess the general governance status in the countries in which these projects are meant to be driven. Table 11 shows some indicators that could reflect in some way the quality of public policies and the good governance standing. Regarding corruption, the indicators show that in general all the countries perform poorly (all the indicators are negative). With respect to transparency and general governance quality, the situation in the countries is not satisfactory, although in comparative terms India outperform its peer countries by having relatively higher scores.

Table 11: Governance indicators (2016)

Country	Corruption index	Transparency index (voice and accountability score)	Governance quality (Government effectiveness)
Bangladesh	-0.80	-0.56	-0.69
India	-0.30	0.41	0.10
Laos	-0.93	-1.73	-0.39
Myanmar	-0.65	-0.85	-0.98
Nepal	-0.76	-0.23	-0.81
Sri Lanka	-0.28	-0.11	-0.21

Source: Based on Worldwide Governance Indicators (WGI) of World Bank
Note: Indices range from -2.5 to 2.5, the most negative values reflect the worst condition.

Corruption rates and governance quality also somehow affect the costs of doing business. As shown in Table 12, the indexes for the cost and time to start business across the studied countries varied between 72 and 88. In terms of the costs and time to start, Sri Lanka is identified as the top performer among the six. The index reflecting the cost of closing business is more heterogeneous varying between 20 and 48 across the studied countries. Finally, the positions of the countries in the Ease of Doing Business ranking reflect in general a weak business environment, as none of these economies lie among the top 100 performers across the globe. However, in South Asian region, business climate is more favorable in India, Nepal and Sri Lanka than the remaining countries.

Table 12: Business environment

Country	Cost and time to start business	Cost to close business	Enabling environment [Ease of doing Business rank among 190 countries (1 is best)]
Bangladesh	80.7	27.7	177
India	75.4	40.8	100
Laos	72.6	No data	141
Myanmar	75.4	20.4	171
Nepal	84.0	48.2	105
Sri Lanka	87.7	44.9	111

Source: Based on World Bank (2018)

Note: 'Cost and Time to start a business' and 'Cost to close business' indices are expressed as the 'Distance to the frontier' (DTF), i.e., a low score represents a more adverse scenario in terms of starting and closing businesses.

Given that organic fertilizer from biodegradable waste is attractive RRR option in South Asia because of high share of rural population, dominance of agriculture among economic activities, and high levels of fertilizer imports, the costs and time for registering new fertilizer was also discussed here (Table 13). Costs and time for registering new fertilizer or soil amendment are quite unfavorable in Nepal as it may take almost four years. Though costs are not so much high, time for registration takes almost three years in India and Bangladesh. In Sri Lanka, one year can be sufficient to test new fertilizer effectiveness and the costs for registration is only 4% of average per capita income.

Table 13: Easiness of registering new fertilizer

Economy	Fertilizer registration index (0-7)	Quality control of fertilizer index (0-7)	Time to register a new fertilizer product (days)	Cost to register a new fertilizer product (% income per capita)
Bangladesh	4.4	4.5	945	58.8
India	5.0	3.5	804	17.1
Lao PDR	3.4	5.0	No Data	0.5
Myanmar	4.4	3.0	41	7.3
Nepal	3.4	5.0	1125	645.2
Sri Lanka	2.4	3.5	365	3.7

Source: Based on World Bank (2017a)

10 Institutional framework for supporting organic waste management

10.1 Central government

Institutional framework and clear distribution of roles and responsibilities are essential for proper functioning of the waste management system. The role of institutions in South Asia regarding waste management could be distinguished in three levels: central government, regional/local governments and NGOs and civil society organizations (ADB 2011). The role of central government institutions consists of setting standards and policies and establishing coordination across different governance levels. However, the ministries involved are diverse and they have different roles related with the waste management activities.

In a broad perspective, the Ministry of Environment is the institution in charge of setting the national policy on waste management and the compliance of the subnational governments and other institutions with these regulations. In addition, in some countries, the Ministry of Environment is the ruling organization in charge of policies and measures on pollution control and environmental regulations. The Ministry of Agriculture has the role of setting an effective policy in the sector, setting the standards for soil preparation, and certifying the uses of organic and inorganic fertilizers. In this sense, this Ministry plays a key role in order to incentivize the use of organic fertilizers through subsidies, information campaigns and regulatory guidelines.

Other important Ministries that could play a role in the waste management are the Ministry of Urban Development and the Ministry of Energy. The Ministry of Urban Development deals with the management of waste in urban areas and plays pivotal role in developing policies for enabling recycling organic waste. The Ministry of Energy, in turn, deals with providing incentives and guidelines for generating renewable energy from organic waste and facilitating the related infrastructural setup. In addition to set policies, the Ministry could also impose the provision of subsidies or other incentives for triggering the implementation of RRR technologies.

The Ministry of Finance and the Ministry of Information have broader roles in terms of facilitating the process of adopting RRR options. Since the Ministry of Finance is in charge of the budget and tax policy overall the ministry provides institutional framework for improving the financial feasibility of RRR options. The Ministry of Information is in charge of the ample communicational policy of the government in general and it could launch the outreach and awareness campaigns regarding sustainable waste and wastewater management options.

Expert surveys indicated lack of cooperation among the ministries and the disputes over conflicting interests prevent successful reforms in the sanitation and environmental protection. Furthermore, since issues of proper sanitation and environmental safeguarding are not prioritized in governmental budget allocation policies investments and subsidies to construct large scale plants to recycle organic waste are very limited.

10.2 Regional/local governments

While the role of central government institutions lies on setting the rules for a proper waste management, the regional governments are actually the ones that potentially carry out the waste reduction, re-use, recycling activities at the local level. In this sense, their tasks are much more diverse than the tasks of the specialized agencies of central government. Some of the tasks for local governments related with waste management are the following (ADB 2011):

- Ensuring land policies for organic waste management;
- Establishing incentives for the private participation in RRR activities;

- Promoting the use of RRR technologies, by creating public awareness;
- Providing infrastructural support (e.g., municipal roads) to enhance the RRR activities;
- Collecting and managing information regarding waste management in order to enhance the process and adjust the procedures.

10.3 Civil Society and NGOs

Civil Society organizations and NGOs are entities in charge of facilitating and implementing the policies addressed to promote the waste management process. Their roles are rather framed in the functions of local governments. For example, they might help to raise community awareness regarding a proper waste behavior (e.g., separating garbage and correct disposal), manage information campaigns and work together with local governments to incentivize the waste reduction, re-use and recycling process. Unwillingness of the government to cooperate with NGOs, legislate the initiatives for sustainable environment, and recognize the private sector initiatives in some countries such as Nepal were earlier reported (Dangi et al. 2013). This attitude prevented the flow of sufficient funds for implementing RRR options and ensuring environmental security.

11 Summary and conclusions

Improved sanitation and wastewater management are important for environmental sustainability and health security in vast areas of South and Southeast Asia. As review results indicated, open defecation is a major problem in India and Nepal due to lack of proper sanitation facilities and psychological barriers. In Laos and Myanmar, sludge and wastewater collection and treatment was quite underdeveloped. Although sanitation facilities are available, wastewater treatment are not adequate or sufficient to meet health and environmental safety guidelines in Bangladesh and Sri Lanka. Underdevelopment and mismanagement along sanitation value chain processes before pre-treatment may dramatically reduce the feasibility of adopting advanced RRR options.

Some level of recycling sludge and organic waste through producing biogas or compost exist in India, Bangladesh, Nepal and Sri Lanka. Lack of spare parts for machines in mechanical composting and inadequate access to electricity in India, government interventions to prevent NGO support for big size compost plants in Nepal, and public protests over malodor in Sri Lanka were found out as main issues. Acceptance of organic waste mixed with inorganic waste, difficulties in obtaining or expanding land for compost plants and lack of demand due to low quality of the compost are common problems in all countries under the study.

Biogas was initially promoted in South and Southeast Asia as a response to skyrocketing energy prices across the globe during the energy crisis in 1970s. Hot temperature in the tropical areas of these regions is very favorable for efficient functioning of biogas plants. Biogas digesters are implemented by many households in plain and hill regions of Nepal with the support of government subsidies. Mostly hotels, some hospitals and farmers adopted biogas technology because of its high construction and utilization costs in Sri Lanka. Installation of biogas digestion units are also enhanced through sanitation and environmental protection laws, which require enterprises and new houses to manage and recycle their waste for obtaining construction and operation permits.

Analysis of demand for fertilizer and energy indicated rapidly growing uses of fertilizers and energy in the studied countries. Nepal, Sri Lanka and Myanmar are fully dependent on imports of phosphate fertilizers. Energy imports or firewood collection for cooking in rural areas are also substantial in this region. Thus, compost and biogas from organic waste can considerably lower deforestation and the expenditures to fossil fuel and chemical fertilizers. Since majority of population lives in rural areas and their livelihoods are heavily dependent on agricultural sector, increased use of organic fertilizer may also play a pivotal role for improving food security and alleviating poverty in these locations.

Insufficient financial resources, inadequate access to bank loans, high levels of corruption and lack of transparency are key barriers for a wider adoption of RRR options in the studied countries. General lack of awareness on environmental safeguarding and indifference towards environmental security imped the potential technological changes, maintaining the continuity of waste and wastewater related pollution. Manual scavenging and improper handling the composting and biogas generating facilities may increase health risks. Lack of adequate demand for fertilizer or biogas in urban areas where most of the organic waste is generated may limit the feasibility of RRR technologies. Underdevelopment of ICT limits interactions between producers and customers, consequently preventing efficient functioning of markets for compost and biogas.

For a wider implementation of RRR options, first of all, a proper accounting, planning and management along the entire sanitation and waste management chain should be established to prevent leakages and ensure a safe disposal of the waste. Because of high poverty rates, the governments may consider subsidizing the implementation of composting and anaerobic digesters. The governments should be also supportive of non-governmental organizations and international donors in their efforts for maintaining sustainable environment and livelihoods through increased recycling waste and wastewater. Since public services along sanitation and recycling chains are not efficient in most of the places, public-private collaborations in the sector should be promoted. Obtaining permissions to land use for constructing compost or biogas plants as well as registering fertilizer products should be easier and more transparent. Enforcing the environmental and sanitation laws to reduce open dumping of waste may result in a wider adoption of RRR options. For raising the awareness of population on environmental and health risks and the relevance of RRR technologies for addressing such issues, organization of education and extension programs can be effective as demonstrated in the example of food hygiene education in Bangladesh (Hasan 2018). Improved ICT could support not only a wider outreach of RRR options but also fruitful interactions of producers and consumers, consequently enhancing the marketability of the RRR products. Finally yet importantly, certifying and monitoring the quality of the RRR facilities and recovered products (e.g., compost, biogas, etc.) are important for nurturing trust and maintaining the continuity of demand for RRR products.

References

Ahluwalia I.J., U. Patel, 2018. Solid Waste Management in India An Assessment of Resource Recovery and Environmental Impact. Indian Council for Research on International Economic Relations (ICRIER), New Dehli, India.

Asian Development Bank (ADB), 2011. Toward Sustainable Municipal Organic Waste Management in South Asia. A guidebook for policy makers and practitioners. Available online at: www.adb.org/sites/default/files/publication/29082/sustainable-waste-management-south-asia.pdf (Accessed on 10.01.2018)

Asian Development Bank (ADB), 2013. Myanmar: Urban development and water sector assessment, strategy, and road map. Mandaluyong City, Philippines.

Asian Development Bank (ADB), 2015. SRI: Greater Colombo Water and Wastewater Management Improvement Program (Project 3) – Wastewater Improvement Project. ADB, Colombo, Sri Lanka.

Bahauddin, K.M., Salahuddin, T.M., 2012. Prospect and trend of renewable energy and its technology towards climate change mitigation and sustainable development in Bangladesh. Int J Adv Renew Energy Res, 1, 156–166.

Bekchanov, 2017a. Potentials of Waste and Wastewater Resources Recovery and Re-use (RRR) Options for Improving Water, Energy and Nutrition Security. ZEF Working Paper No 157. Center for Development Research (ZEF), Bonn University, Bonn, Germany.

Bekchanov, 2017b. Enabling Environment for Waste and Wastewater Recycling and Reuse Options in South Asia: the case of Sri Lanka. ZEF Working Paper No 163. Center for Development Research (ZEF), Bonn University, Bonn, Germany.

Biogas Support Programme (BSP), 2012. Biogas Support Programme (BSP) 2011/2012. BSP, Lalitpur, Nepal. Available online at: http://www.bspnepal.org.np/?option=publication (Accessed on 01.03.2018)

Cairns-Smith, S., Hill, H. & Nazarenko, E., 2014. Urban Sanitation: Why a Portfolio of Solutions is Needed. The Boston Consulting Group, Boston, USA.

Chandran, M., 2012. Composting in SWM – A Report, 2012. Clean India Journal, Issue on April 19 2012. Available online at: https://www.cleanindiajournal.com/composting_in_swm%E2%80%93a_report/ (Accessed on 15.01.2018)

Corcoran, E., Nellemann, C., Baker, E., Bos, R., Osborn, D., Savelli, H. (eds), 2010. Sick Water? The central role of wastewater management in sustainable development. A Rapid Response Assessment. United Nations Environment Programme, UN-HABITAT, GRID-Arendal. www.grida.no

Cordell, D., Rosemarin, A., Schröder, J. J., Smit, A.L., 2011. Towards global phosphorus security: a systems framework for phosphorus recovery and reuse options. Chemosphere 84, 747–758.

CPCB, 2013. Consolidated Annual Review Report on Implementation of Municipal Solid Wastes (Management and Handling) Rules, 2000. C.P.C. BOARD (Ed.), Ministry of Environment Forests & Climate Change, New Delhi.

CSO, 2014. Energy Statistics. C.S. Office (Ed.), Ministry of Statistics and Programme Implementation, New Delhi.

Dangi, M.B., Urynowicz, M.A., Belbase, S., 2013. Characterization, generation, and management of household solid waste in Tulsipur, Nepal. Habitat Int., 40, 65-72.

de Alwis, A., 2002. Biogas – a review of Sri Lanka's performance with a renewable energy technology. Energy for Sustainable Development, 6(1), 30-37.

Deo, P., Modak, S., Shukla, P.R., 1991. Decentralized energy planning. New Delhi, India, Oxford and IBH Publishing Co. Pvt. Ltd.

Food and Agricultural Organization (FAO), 2013. Enabling environments for agribusiness and agro-industries development – Regional and country perspectives. Rome.

Food and Agricultural Organization (FAO), 2018. FAOSTAT – Online database. Available online at: www.fao.org/faostat/en/#data (Accessed on 12.06.2017)

Gautam, R., Baral, S., Herat, S., 2009. Biogas as a sustainable energy source in Nepal: Present status and future challenges. Renewable and Sustainable Energy Reviews, 13, 248–252.

Gunawan, A., Schoebitz, L., Strande, L., 2015. SFD Report Khulna, Bangladesh. Eawag/Sandec, Dübendorf, Zwitzerland.

Halder, P.K., Paul, N., Joardder, M.U.H., Khan, M.Z.H., Sarker, M., 2012. Feasibility analysis of implementing anaerobic digestion as a potential energy source in Bangladesh. Renewable and Sustainable Energy Reviews, 65, 124–134.

Hasan, M.M., Gerber, N, 2016. The impacts of piped water on water quality, sanitation, hygiene and health in rural households of north-western Bangladesh: A quasi-experimental analysis. ZEF-Discussion Papers on Development Policy, No. 217

Hasan, M.M., 2018. Investment in health within the agriculture, water, sanitation and hygiene nexus for rural households in Bangladesh. 2018. Doctoral Dissertation. http://hss.ulb.uni-bonn.de/2018/4988/4988.htm

Höök, M., Tang, X., 2013. Depletion of fossil fuels and anthropogenic climate change—A review. Energy Policy 52, 797–809.

HPCIDBC, 2011. Status and Strategy for Fecal Sludge Management in the Kathmandu Valley, High Powered Committee for Integrated Development of the Bagmati Civilization, Kathmandu, Nepal.

Hutton, G., Haller, L., Bartram, J., 2007. Global Cost-Benefit Analysis of Water Supply and Sanitation Interventions. J Water Health 5, 481–502.

ICIMOD, Government of Nepal (GoN), UNEP, 2007. Kathmandu Valley Environmental Outlook, International Centre for Integrated Mountain Development (ICIMOD): Kathmandu, Nepal.

Infrastructure Development Company Limited (IDCOL), 2016. Available online at: http://idcol.org/home/other_re (Accessed on 25.01.2018)

Japan International Cooperation Agency (JICA), 2006. Data collection survey on solid waste management in Democratic Socialist Republic of Sri Lanka. Final Report.

Lagerblad, L., 2010. Wastewater treatment wetlands – A case study in Colombo, Sri Lanka. MSc Thesis, University of Upsala, Sweden.

Lazarova, V., Asano, T., Bahri, A., Anderson, J., 2013. Milestones in water reuse. The best success stories. London, UK: IWA Publishing.

Maheshi, D., Steven, V.P., Karel, V.A., 2015. Environmental and economic assessment of 'open waste dump'mining in Sri Lanka. Resources, Conservation and Recycling, 102, 67–79.

Mamun-ur-Rashid, M. (2013). Vermicompost or Kecho Fertilizer. September, Krishi Bartha, Krishi Foundation, Krishibid Group, Kazipara, Mirpur, Dhaka.

Mittal, Sh., Ahlgren, E.O., Shukla, P.R., 2018. Barriers to biogas dissemination in India: A review. Energy Policy, 112, 361-370.

Nyachhyon, B.L., 2006. Service Enhancement and Development of Sanitary Sewarage System in Urban and Semi-Urban Setting in Nepal, Policy Paper 23, prepared for Economic Policy Network, Ministry of Finance (MOF)/HMGN and Asian Development Bank (ADB) Nepal Resident Mission, Kathmandu, Nepal.

Opel, A., Bashar, M.K., Ahmed, M.F., 2012. Faecal sludge management in Bangladesh: an issue that needs urgent attention. Asia Regional Sanitation and Hygiene Practitioners Workshop, Dhaka, Bangladesh.

Opel, A., Cheuasongkham, P., 2015. Faecal Sludge Management Services in Rural Laos: Critical Gaps and Important Ways Forward, 3rd Faecal Sludge Management Conference, Hanoi, Vietnam.

Pandey, MR., 1984. Domestic smoke pollution and chronic bronchitis in a rural community of the hill region of Nepal. Thorax, 39, 337–9.

Pandyaswargo, A.H., Premakumara, D.G.J., 2012. Financial sustainability of modern composting: the economically optimal scale for municipal waste composting plant in developing Asia. Int J Recycl Org Waste Agricult, 3, 66.doi: 10.1007/s40093-014-0066-y.

Premakumara, D.G.J., Hengesbaugh, M., Onogawa, K., Hlaing, O.M.T., 2017. Waste Management in Myanmar: Current Status, Key Challenges and Recommendations for National and City Waste Management Strategies. Institute for Global Environmental Strategies (IGES), Kanagawa, Japan.

Rashid, S. Z., 2011. Composting and Use of Compost for Organic Agriculture in Bangladesh. In: Proceedings of the 4th International Conference for the Development of Integrated Pest Management in Asia and Africa, pp. 20-22.

Shrestha, R.R., 1999. Application of Constructed Wetlands for Wastewater Treatment in Nepal, Ph.D. Dissertation, Department of Sanitary Engineering and Water Pollution Control, University of Agricultural Sciences Vienna, Austria.

Strande, L., Ronteltap, M., Brdjanovic, D. (Eds.), 2014. Faecal Sludge Management (FSM) book - Systems Approach for Implementation and Operation. IWA Publishing, UK.

Sunday Times (A Newspaper), 2017. Marine Pollution around Sri Lanka and the inevitable environmental disaster, Issue on 09 April 2017.

The Laotian Times, 2018. Vientiane's First Fecal Sludge Treatment Plant Launches (Newspaper article). Online at: https://laotiantimes.com/2017/12/11/vientianes-first-fecal-sludge-treatment-plant-launches/ (Accessed on 10.01.2018)

United Nation (UN), 2016. The Sustainable Development Goals Report 2016. UN, New York.

United Nations Environmental Program (UNEP), 2001. Annual report: Sri Lanka: State of the environment 2001. Regional Resource Centre for Asia and the Pacific UNEP, Pathumthani, Thailand.

United Nations Environmental Program (UNEP), 2017. Asia Waste Management Outlook. Available online at: http://web.unep.org/ietc/sites/unep.org.ietc/files/Asia%20outlook_ENG.pdf (Accessed on 24.01.2018)

UN-HABITAT, 2010. Solid waste management in the world's cities: water and sanitation in the world's cities 2010. London, Earthscan.

UN-Water, 2016: Water and Sanitation Interlinkages across the 2030 Agenda for Sustainable Development. Geneva.

Vangani, R., Saxena, D., Gerber, N., Mavalankar, D. and J. von Braun, 2016. Impact of different irrigation systems on water quality in peri-urban areas of Gujarat, India. ZEF-Discussion Papers on Development Policy, No. 217

Visvanathan, C., Glawe, U., 2006. Domestic Solid Waste Management in South Asian Countries - A Comparative Analysis. Paper presented at 3R South Asia Expert Workshop, 30 August - 1 September, 2006, Kathmandu, Nepal.

World Bank, 2015. Doing business 2015: Going beyond efficiency. World Bank Group, Washington DC.

World Bank, 2016. Fecal Sludge Management: Diagnostics for Service Delivery in Urban Areas: Case study in Dhaka, Bangladesh. Supporting document.

World Bank 2017a. Enabling the business of Agriculture 2017. Available online at: http://eba.worldbank.org/~/media/WBG/AgriBusiness/Documents/Reports/2017/EBA-Full-Report.pdf?la=en (Accessed on 02.03.2018)

World Bank, 2017b. World Development Indicators. Online database. Available online at: http://wdi.worldbank.org/tables (Accessed on 25.01.2018)

World Bank, 2018. Doing business report 2018: Reforming to Create Jobs. Available online at: http://www.doingbusiness.org/~/media/WBG/DoingBusiness/Documents/Annual-Reports/English/DB2018-Full-Report.pdf (Accessed on 25.01.2018)

WHO/UNICEF JMP, 2014. Estimates on the use of water sources and sanitation facilities of Lao PDR (updated, April 2014). Joint Monitoring Programme for Water Supply and Sanitation. 2

WWAP (United Nations World Water Assessment Programme), 2017. The United Nations World Water Development Report 2017. Wastewater: The Untapped Resource. Paris, UNESCO.

Zaw, K., (n.d.). Current status of Myanmar on sewage and sanitation. Available online at: http://www.fukuoka.unhabitat.org/kcap/activities/egm/2011/pdf/Myanmar.pdf (Accessed on 01.02.2018)

ZEF Working Paper Series, ISSN 1864-6638
Center for Development Research, University of Bonn
Editors: Christian Borgemeister, Joachim von Braun, Manfred Denich, Till Stellmacher and Eva Youkhana

1. Evers, Hans-Dieter and Solvay Gerke (2005). Closing the Digital Divide: Southeast Asia's Path Towards a Knowledge Society.
2. Bhuiyan, Shajahan and Hans-Dieter Evers (2005). Social Capital and Sustainable Development: Theories and Concepts.
3. Schetter, Conrad (2005). Ethnicity and the Political Reconstruction of Afghanistan.
4. Kassahun, Samson (2005). Social Capital and Community Efficacy. In Poor Localities of Addis Ababa Ethiopia.
5. Fuest, Veronika (2005). Policies, Practices and Outcomes of Demand-oriented Community Water Supply in Ghana: The National Community Water and Sanitation Programme 1994 – 2004.
6. Menkhoff, Thomas and Hans-Dieter Evers (2005). Strategic Groups in a Knowledge Society: Knowledge Elites as Drivers of Biotechnology Development in Singapore.
7. Mollinga, Peter P. (2005). The Water Resources Policy Process in India: Centralisation, Polarisation and New Demands on Governance.
8. Evers, Hans-Dieter (2005). Wissen ist Macht: Experten als Strategische Gruppe.
8.a Evers, Hans-Dieter and Solvay Gerke (2005). Knowledge is Power: Experts as Strategic Group.
9. Fuest, Veronika (2005). Partnerschaft, Patronage oder Paternalismus? Eine empirische Analyse der Praxis universitärer Forschungskooperation mit Entwicklungsländern.
10. Laube, Wolfram (2005). Promise and Perils of Water Reform: Perspectives from Northern Ghana.
11. Mollinga, Peter P. (2004). Sleeping with the Enemy: Dichotomies and Polarisation in Indian Policy Debates on the Environmental and Social Effects of Irrigation.
12. Wall, Caleb (2006). Knowledge for Development: Local and External Knowledge in Development Research.
13. Laube, Wolfram and Eva Youkhana (2006). Cultural, Socio-Economic and Political Con-straints for Virtual Water Trade: Perspectives from the Volta Basin, West Africa.
14. Hornidge, Anna-Katharina (2006). Singapore: The Knowledge-Hub in the Straits of Malacca.
15. Evers, Hans-Dieter and Caleb Wall (2006). Knowledge Loss: Managing Local Knowledge in Rural Uzbekistan.
16. Youkhana, Eva; Lautze, J. and B. Barry (2006). Changing Interfaces in Volta Basin Water Management: Customary, National and Transboundary.
17. Evers, Hans-Dieter and Solvay Gerke (2006). The Strategic Importance of the Straits of Malacca for World Trade and Regional Development.
18. Hornidge, Anna-Katharina (2006). Defining Knowledge in Germany and Singapore: Do the Country-Specific Definitions of Knowledge Converge?
19. Mollinga, Peter M. (2007). Water Policy – Water Politics: Social Engineering and Strategic Action in Water Sector Reform.
20. Evers, Hans-Dieter and Anna-Katharina Hornidge (2007). Knowledge Hubs Along the Straits of Malacca.
21. Sultana, Nayeem (2007). Trans-National Identities, Modes of Networking and Integration in a Multi-Cultural Society. A Study of Migrant Bangladeshis in Peninsular Malaysia.
22. Yalcin, Resul and Peter M. Mollinga (2007). Institutional Transformation in Uzbekistan's Agricultural and Water Resources Administration: The Creation of a New Bureaucracy.
23. Menkhoff, T.; Loh, P. H. M.; Chua, S. B.; Evers, H.-D. and Chay Yue Wah (2007). Riau Vegetables for Singapore Consumers: A Collaborative Knowledge-Transfer Project Across the Straits of Malacca.
24. Evers, Hans-Dieter and Solvay Gerke (2007). Social and Cultural Dimensions of Market Expansion.
25. Obeng, G. Y.; Evers, H.-D.; Akuffo, F. O., Braimah, I. and A. Brew-Hammond (2007). Solar PV Rural Electrification and Energy-Poverty Assessment in Ghana: A Principal Component Analysis.

26. Eguavoen, Irit; E. Youkhana (2008). Small Towns Face Big Challenge. The Management of Piped Systems after the Water Sector Reform in Ghana.

27. Evers, Hans-Dieter (2008). Knowledge Hubs and Knowledge Clusters: Designing a Knowledge Architecture for Development

28. Ampomah, Ben Y.; Adjei, B. and E. Youkhana (2008). The Transboundary Water Resources Management Regime of the Volta Basin.

29. Saravanan.V.S.; McDonald, Geoffrey T. and Peter P. Mollinga (2008). Critical Review of Integrated Water Resources Management: Moving Beyond Polarised Discourse.

30. Laube, Wolfram; Awo, Martha and Benjamin Schraven (2008). Erratic Rains and Erratic Markets: Environmental change, economic globalisation and the expansion of shallow groundwater irrigation in West Africa.

31. Mollinga, Peter P. (2008). For a Political Sociology of Water Resources Management.

32. Hauck, Jennifer; Youkhana, Eva (2008). Histories of water and fisheries management in Northern Ghana.

33. Mollinga, Peter P. (2008). The Rational Organisation of Dissent. Boundary concepts, boundary objects and boundary settings in the interdisciplinary study of natural resources management.

34. Evers, Hans-Dieter; Gerke, Solvay (2009). Strategic Group Analysis.

35. Evers, Hans-Dieter; Benedikter, Simon (2009). Strategic Group Formation in the Mekong Delta - The Development of a Modern Hydraulic Society.

36. Obeng, George Yaw; Evers, Hans-Dieter (2009). Solar PV Rural Electrification and Energy-Poverty: A Review and Conceptual Framework With Reference to Ghana.

37. Scholtes, Fabian (2009). Analysing and explaining power in a capability perspective.

38. Eguavoen, Irit (2009). The Acquisition of Water Storage Facilities in the Abay River Basin, Ethiopia.

39. Hornidge, Anna-Katharina; Mehmood Ul Hassan; Mollinga, Peter P. (2009). 'Follow the Innovation' – A joint experimentation and learning approach to transdisciplinary innovation research.

40. Scholtes, Fabian (2009). How does moral knowledge matter in development practice, and how can it be researched?

41. Laube, Wolfram (2009). Creative Bureaucracy: Balancing power in irrigation administration in northern Ghana.

42. Laube, Wolfram (2009). Changing the Course of History? Implementing water reforms in Ghana and South Africa.

43. Scholtes, Fabian (2009). Status quo and prospects of smallholders in the Brazilian sugarcane and ethanol sector: Lessons for development and poverty reduction.

44. Evers, Hans-Dieter; Genschick, Sven; Schraven, Benjamin (2009). Constructing Epistemic Landscapes: Methods of GIS-Based Mapping.

45. Saravanan V.S. (2009). Integration of Policies in Framing Water Management Problem: Analysing Policy Processes using a Bayesian Network.

46. Saravanan V.S. (2009). Dancing to the Tune of Democracy: Agents Negotiating Power to Decentralise Water Management.

47. Huu, Pham Cong; Rhlers, Eckart; Saravanan, V. Subramanian (2009). Dyke System Planing: Theory and Practice in Can Tho City, Vietnam.

48. Evers, Hans-Dieter; Bauer, Tatjana (2009). Emerging Epistemic Landscapes: Knowledge Clusters in Ho Chi Minh City and the Mekong Delta.

49. Reis, Nadine; Mollinga, Peter P. (2009). Microcredit for Rural Water Supply and Sanitation in the Mekong Delta. Policy implementation between the needs for clean water and 'beautiful latrines'.

50. Gerke, Solvay; Ehlert, Judith (2009). Local Knowledge as Strategic Resource: Fishery in the Seasonal Floodplains of the Mekong Delta, Vietnam

51. Schraven, Benjamin; Eguavoen, Irit; Manske, Günther (2009). Doctoral degrees for capacity development: Results from a survey among African BiGS-DR alumni.

52. Nguyen, Loan (2010). Legal Framework of the Water Sector in Vietnam.

53. Nguyen, Loan (2010). Problems of Law Enforcement in Vietnam. The Case of Wastewater Management in Can Tho City.

54. Oberkircher, Lisa et al. (2010). Rethinking Water Management in Khorezm, Uzbekistan. Concepts and Recommendations.

55. Waibel, Gabi (2010). State Management in Transition: Understanding Water Resources Management in Vietnam.

56. Saravanan V.S.; Mollinga, Peter P. (2010). Water Pollution and Human Health. Transdisciplinary Research on Risk Governance in a Complex Society.

57. Vormoor, Klaus (2010). Water Engineering, Agricultural Development and Socio-Economic Trends in the Mekong Delta, Vietnam.

58. Hornidge, Anna-Katharina; Kurfürst, Sandra (2010). Envisioning the Future, Conceptualising Public Space. Hanoi and Singapore Negotiating Spaces for Negotiation.

59. Mollinga, Peter P. (2010). Transdisciplinary Method for Water Pollution and Human Health Research.

60. Youkhana, Eva (2010). Gender and the development of handicraft production in rural Yucatán/Mexico.

61. Naz, Farhat; Saravanan V. Subramanian (2010). Water Management across Space and Time in India.

62. Evers, Hans-Dieter; Nordin, Ramli, Nienkemoer, Pamela (2010). Knowledge Cluster Formation in Peninsular Malaysia: The Emergence of an Epistemic Landscape.

63. Mehmood Ul Hassan; Hornidge, Anna-Katharina (2010). 'Follow the Innovation' – The second year of a joint experimentation and learning approach to transdisciplinary research in Uzbekistan.

64. Mollinga, Peter P. (2010). Boundary concepts for interdisciplinary analysis of irrigation water management in South Asia.

65. Noelle-Karimi, Christine (2006). Village Institutions in the Perception of National and International Actors in Afghanistan. (**Amu Darya Project Working Paper No. 1**)

66. Kuzmits, Bernd (2006). Cross-bordering Water Management in Central Asia. (**Amu Darya Project Working Paper No. 2**)

67. Schetter, Conrad; Glassner, Rainer; Karokhail, Masood (2006). Understanding Local Violence. Security Arrangements in Kandahar, Kunduz and Paktia. (**Amu Darya Project Working Paper No. 3**)

68. Shah, Usman (2007). Livelihoods in the Asqalan and Sufi-Qarayateem Canal Irrigation Systems in the Kunduz River Basin. (**Amu Darya Project Working Paper No. 4**)

69. ter Steege, Bernie (2007). Infrastructure and Water Distribution in the Asqalan and Sufi-Qarayateem Canal Irrigation Systems in the Kunduz River Basin. (**Amu Darya Project Working Paper No. 5**)

70. Mielke, Katja (2007). On The Concept of 'Village' in Northeastern Afghanistan. Explorations from Kunduz Province. (**Amu Darya Project Working Paper No. 6**)

71. Mielke, Katja; Glassner, Rainer; Schetter, Conrad; Yarash, Nasratullah (2007). Local Governance in Warsaj and Farkhar Districts. (**Amu Darya Project Working Paper No. 7**)

72. Meininghaus, Esther (2007). Legal Pluralism in Afghanistan. (**Amu Darya Project Working Paper No. 8**)

73. Yarash, Nasratullah; Smith, Paul; Mielke, Katja (2010). The fuel economy of mountain villages in Ishkamish and Burka (Northeast Afghanistan). Rural subsistence and urban marketing patterns. (**Amu Darya Project Working Paper No. 9**)

74. Oberkircher, Lisa (2011). 'Stay – We Will Serve You Plov!'. Puzzles and pitfalls of water research in rural Uzbekistan.

75. Shtaltovna, Anastasiya; Hornidge, Anna-Katharina; Mollinga, Peter P. (2011). The Reinvention of Agricultural Service Organisations in Uzbekistan – a Machine-Tractor Park in the Khorezm Region.

76. Stellmacher, Till; Grote, Ulrike (2011). Forest Coffee Certification in Ethiopia: Economic Boon or Ecological Bane?
77. Gatzweiler, Franz W.; Baumüller, Heike; Ladenburger, Christine; von Braun, Joachim (2011). Marginality. Addressing the roots causes of extreme poverty.
78. Mielke, Katja; Schetter, Conrad; Wilde, Andreas (2011). Dimensions of Social Order: Empirical Fact, Analytical Framework and Boundary Concept.
79. Yarash, Nasratullah; Mielke, Katja (2011). The Social Order of the Bazaar: Socio-economic embedding of Retail and Trade in Kunduz and Imam Sahib
80. Baumüller, Heike; Ladenburger, Christine; von Braun, Joachim (2011). Innovative business approaches for the reduction of extreme poverty and marginality?
81. Ziai, Aram (2011). Some reflections on the concept of 'development'.
82. Saravanan V.S., Mollinga, Peter P. (2011). The Environment and Human Health - An Agenda for Research.
83. Eguavoen, Irit; Tesfai, Weyni (2011). Rebuilding livelihoods after dam-induced relocation in Koga, Blue Nile basin, Ethiopia.
84. Eguavoen, I., Sisay Demeku Derib et al. (2011). Digging, damming or diverting? Small-scale irrigation in the Blue Nile basin, Ethiopia.
85. Genschick, Sven (2011). Pangasius at risk - Governance in farming and processing, and the role of different capital.
86. Quy-Hanh Nguyen, Hans-Dieter Evers (2011). Farmers as knowledge brokers: Analysing three cases from Vietnam's Mekong Delta.
87. Poos, Wolf Henrik (2011). The local governance of social security in rural Surkhondarya, Uzbekistan. Post-Soviet community, state and social order.
88. Graw, Valerie; Ladenburger, Christine (2012). Mapping Marginality Hotspots. Geographical Targeting for Poverty Reduction.
89. Gerke, Solvay; Evers, Hans-Dieter (2012). Looking East, looking West: Penang as a Knowledge Hub.
90. Turaeva, Rano (2012). Innovation policies in Uzbekistan: Path taken by ZEFa project on innovations in the sphere of agriculture.
91. Gleisberg-Gerber, Katrin (2012). Livelihoods and land management in the Ioba Province in south-western Burkina Faso.
92. Hiemenz, Ulrich (2012). The Politics of the Fight Against Food Price Volatility – Where do we stand and where are we heading?
93. Baumüller, Heike (2012). Facilitating agricultural technology adoption among the poor: The role of service delivery through mobile phones.
94. Akpabio, Emmanuel M.; Saravanan V.S. (2012). Water Supply and Sanitation Practices in Nigeria: Applying Local Ecological Knowledge to Understand Complexity.
95. Evers, Hans-Dieter; Nordin, Ramli (2012). The Symbolic Universe of Cyberjaya, Malaysia.
96. Akpabio, Emmanuel M. (2012). Water Supply and Sanitation Services Sector in Nigeria: The Policy Trend and Practice Constraints.
97. Boboyorov, Hafiz (2012). Masters and Networks of Knowledge Production and Transfer in the Cotton Sector of Southern Tajikistan.
98. Van Assche, Kristof; Hornidge, Anna-Katharina (2012). Knowledge in rural transitions - formal and informal underpinnings of land governance in Khorezm.
99. Eguavoen, Irit (2012). Blessing and destruction. Climate change and trajectories of blame in Northern Ghana.
100. Callo-Concha, Daniel; Gaiser, Thomas and Ewert, Frank (2012). Farming and cropping systems in the West African Sudanian Savanna. WASCAL research area: Northern Ghana, Southwest Burkina Faso and Northern Benin.

101. Sow, Papa (2012). Uncertainties and conflicting environmental adaptation strategies in the region of the Pink Lake, Senegal.
102. Tan, Siwei (2012). Reconsidering the Vietnamese development vision of "industrialisation and modernisation by 2020".
103. Ziai, Aram (2012). Postcolonial perspectives on 'development'.
104. Kelboro, Girma; Stellmacher, Till (2012). Contesting the National Park theorem? Governance and land use in Nech Sar National Park, Ethiopia.
105. Kotsila, Panagiota (2012). "Health is gold": Institutional structures and the realities of health access in the Mekong Delta, Vietnam.
106. Mandler, Andreas (2013). Knowledge and Governance Arrangements in Agricultural Production: Negotiating Access to Arable Land in Zarafshan Valley, Tajikistan.
107. Tsegai, Daniel; McBain, Florence; Tischbein, Bernhard (2013). Water, sanitation and hygiene: the missing link with agriculture.
108. Pangaribowo, Evita Hanie; Gerber, Nicolas; Torero, Maximo (2013). Food and Nutrition Security Indicators: A Review.
109. von Braun, Joachim; Gerber, Nicolas; Mirzabaev, Alisher; Nkonya Ephraim (2013). The Economics of Land Degradation.
110. Stellmacher, Till (2013). Local forest governance in Ethiopia: Between legal pluralism and livelihood realities.
111. Evers, Hans-Dieter; Purwaningrum, Farah (2013). Japanese Automobile Conglomerates in Indonesia: Knowledge Transfer within an Industrial Cluster in the Jakarta Metropolitan Area.
112. Waibel, Gabi; Benedikter, Simon (2013). The formation water user groups in a nexus of central directives and local administration in the Mekong Delta, Vietnam.
113. Ayaribilla Akudugu, Jonas; Laube, Wolfram (2013). Implementing Local Economic Development in Ghana: Multiple Actors and Rationalities.
114. Malek, Mohammad Abdul; Hossain, Md. Amzad; Saha, Ratnajit; Gatzweiler, Franz W. (2013). Mapping marginality hotspots and agricultural potentials in Bangladesh.
115. Siriwardane, Rapti; Winands, Sarah (2013). Between hope and hype: Traditional knowledge(s) held by marginal communities.
116. Nguyen, Thi Phuong Loan (2013). The Legal Framework of Vietnam's Water Sector: Update 2013.
117. Shtaltovna, Anastasiya (2013). Knowledge gaps and rural development in Tajikistan. Agricultural advisory services as a panacea?
118. Van Assche, Kristof; Hornidge, Anna-Katharina; Shtaltovna, Anastasiya; Boboyorov, Hafiz (2013). Epistemic cultures, knowledge cultures and the transition of agricultural expertise. Rural development in Tajikistan, Uzbekistan and Georgia.
119. Schädler, Manuel; Gatzweiler, Franz W. (2013). Institutional Environments for Enabling Agricultural Technology Innovations: The role of Land Rights in Ethiopia, Ghana, India and Bangladesh.
120. Eguavoen, Irit; Schulz, Karsten; de Wit, Sara; Weisser, Florian; Müller-Mahn, Detlef (2013). Political dimensions of climate change adaptation. Conceptual reflections and African examples.
121. Feuer, Hart Nadav; Hornidge, Anna-Katharina; Schetter, Conrad (2013). Rebuilding Knowledge. Opportunities and risks for higher education in post-conflict regions.
122. Dörendahl, Esther I. (2013). Boundary work and water resources. Towards improved management and research practice?
123. Baumüller, Heike (2013). Mobile Technology Trends and their Potential for Agricultural Development
124. Saravanan, V.S. (2013). "Blame it on the community, immunize the state and the international agencies." An assessment of water supply and sanitation programs in India.

125. Ariff, Syamimi; Evers, Hans-Dieter; Ndah, Anthony Banyouko; Purwaningrum, Farah (2014). Governing Knowledge for Development: Knowledge Clusters in Brunei Darussalam and Malaysia.
126. Bao, Chao; Jia, Lili (2014). Residential fresh water demand in China. A panel data analysis.
127. Siriwardane, Rapti (2014). War, Migration and Modernity: The Micro-politics of the Hijab in Northeastern Sri Lanka.
128. Kirui, Oliver Kiptoo; Mirzabaev, Alisher (2014). Economics of Land Degradation in Eastern Africa.
129. Evers, Hans-Dieter (2014). Governing Maritime Space: The South China Sea as a Mediterranean Cultural Area.
130. Saravanan, V. S.; Mavalankar, D.; Kulkarni, S.; Nussbaum, S.; Weigelt, M. (2014). Metabolized-water breeding diseases in urban India: Socio-spatiality of water problems and health burden in Ahmedabad.
131. Zulfiqar, Ali; Mujeri, Mustafa K.; Badrun Nessa, Ahmed (2014). Extreme Poverty and Marginality in Bangladesh: Review of Extreme Poverty Focused Innovative Programmes.
132. Schwachula, Anna; Vila Seoane, Maximiliano; Hornidge, Anna-Katharina (2014). Science, technology and innovation in the context of development. An overview of concepts and corresponding policies recommended by international organizations.
133. Callo-Concha, Daniel (2014). Approaches to managing disturbance and change: Resilience, vulnerability and adaptability.
134. Mc Bain, Florence (2014). Health insurance and health environment: India's subsidized health insurance in a context of limited water and sanitation services.
135. Mirzabaev, Alisher; Guta, Dawit; Goedecke, Jann; Gaur, Varun; Börner, Jan; Virchow, Detlef; Denich, Manfred; von Braun, Joachim (2014). Bioenergy, Food Security and Poverty Reduction: Mitigating tradeoffs and promoting synergies along the Water-Energy-Food Security Nexus.
136. Iskandar, Deden Dinar; Gatzweiler, Franz (2014). An optimization model for technology adoption of marginalized smallholders: Theoretical support for matching technological and institutional innovations.
137. Bühler, Dorothee; Grote, Ulrike; Hartje, Rebecca; Ker, Bopha; Lam, Do Truong; Nguyen, Loc Duc; Nguyen, Trung Thanh; Tong, Kimsun (2015). Rural Livelihood Strategies in Cambodia: Evidence from a household survey in Stung Treng.
138. Amankwah, Kwadwo; Shtaltovna, Anastasiya; Kelboro, Girma; Hornidge, Anna-Katharina (2015). A Critical Review of the Follow-the-Innovation Approach: Stakeholder collaboration and agricultural innovation development.
139. Wiesmann, Doris; Biesalski, Hans Konrad; von Grebmer, Klaus; Bernstein, Jill (2015). Methodological review and revision of the Global Hunger Index.
140. Eguavoen, Irit; Wahren, Julia (2015). Climate change adaptation in Burkina Faso: aid dependency and obstacles to political participation. Adaptation au changement climatique au Burkina Faso: la dépendance à l'aide et les obstacles à la participation politique.
141. Youkhana, Eva. Postponed to 2016 (147).
142. Von Braun, Joachim; Kalkuhl, Matthias (2015). International Science and Policy Interaction for Improved Food and Nutrition Security: toward an International Panel on Food and Nutrition (IPFN).
143. Mohr, Anna; Beuchelt, Tina; Schneider, Rafaël; Virchow, Detlef (2015). A rights-based food security principle for biomass sustainability standards and certification systems.
144. Husmann, Christine; von Braun, Joachim; Badiane, Ousmane; Akinbamijo, Yemi; Fatunbi, Oluwole Abiodun; Virchow, Detlef (2015). Tapping Potentials of Innovation for Food Security and Sustainable Agricultural Growth: An Africa-Wide Perspective.
145. Laube, Wolfram (2015). Changing Aspirations, Cultural Models of Success, and Social Mobility in Northern Ghana.
146. Narayanan, Sudha; Gerber, Nicolas (2016). Social Safety Nets for Food and Nutritional Security in India.

147. Youkhana, Eva (2016). Migrants' religious spaces and the power of Christian Saints – the Latin American Virgin of Cisne in Spain.
148. Grote, Ulrike; Neubacher, Frank (2016). Rural Crime in Developing Countries: Theoretical Framework, Empirical Findings, Research Needs.
149. Sharma, Rasadhika; Nguyen, Thanh Tung; Grote, Ulrike; Nguyen, Trung Thanh. Changing Livelihoods in Rural Cambodia: Evidence from panel household data in Stung Treng.
150. Kavegue, Afi; Eguavoen, Irit (2016). The experience and impact of urban floods and pollution in Ebo Town, Greater Banjul Area, in The Gambia.
151. Mbaye, Linguère Mously; Zimmermann, Klaus F. (2016). Natural Disasters and Human Mobility.
152. Gulati, Ashok; Manchanda, Stuti; Kacker, Rakesh (2016). Harvesting Solar Power in India.
153. Laube, Wolfram; Awo, Martha; Derbile, Emmanuel (2017). Smallholder Integration into the Global Shea Nut Commodity Chain in Northern Ghana. Promoting poverty reduction or continuing exploitation?
154. Attemene, Pauline; Eguavoen, Irit (2017). Effects of sustainability communication on environments and rural livelihoods.
155. Von Braun, Joachim; Kofol, Chiara (2017). Expanding Youth Employment in the Arab Region and Africa.
156. Beuchelt, Tina (2017). Buying green and social from abroad: Are biomass-focused voluntary sustainability standards useful for European public procurement?
157. Bekchanov, Maksud (2017). Potentials of Waste and Wastewater Resources Recovery and Re-use (RRR) Options for Improving Water, Energy and Nutrition Security.
158. Leta, Gerba; Kelboro, Girma; Stellmacher, Till; Hornidge, Anna-Katharina (2017). The agricultural extension system in Ethiopia: operational setup, challenges and opportunities.
159. Ganguly, Kavery; Gulati, Ashok; von Braun, Joachim (2017). Innovations spearheading the next transformations in India's agriculture.
160. Gebreselassie, Samuel; Haile Mekbib G.; Kalkuhl, Matthias (2017). The Wheat Sector in Ethiopia: Current Status and Key Challenges for Future Value Chain Development.
161. Jemal, Omarsherif Mohammed, Callo-Concha, Daniel (2017). Potential of Agroforestry for Food and Nutrition Security of Small-scale Farming Households.
162. Berga, Helen; Ringler, Claudia; Bryan, Elizabeth; El Didi, Hagar; Elnasikh Sara (2017). Addressing Transboundary Cooperation in the Eastern Nile through the Water-Energy-Food Nexus. Insights from an E-survey and Key Informant Interviews.
163. Bekchanov, Maksud (2017). Enabling Environment for Waste and Wastewater Recycling and Reuse Options in South Asia: the case of Sri Lanka.
164. Kirui, Oliver Kiptoo; Kozicka, Martha (2018). Vocational Education and Training for Farmers and Other Actors in the Agri-Food Value Chain in Africa.
165. Christinck, Anja; Rattunde, Fred; Kergna, Alpha; Mulinge, Wellington; Weltzien, Eva (2018). Identifying Options for the Development of Sustainable Seed Systems - Insights from Kenya and Mali.
166. Tambo, Justice A. (2018). Recognizing and rewarding farmers' creativity through contests: experiences and insights from four African countries.
167. von Braun, Joachim (2018). Innovations to Overcome the Increasingly Complex Problems of Hunger.
168. Maksud, Bechanov; Evia, Pablo (2018). Sanitation system and investment climate for Resources Recovery and Reuse (RRR) options in South and Southeast Asia: The cases of India, Bangladesh, Nepal, Sri Lanka, Laos and Myanmar.

http://www.zef.de/workingpapers.html

ZEF Development Studies

edited by
Solvay Gerke and Hans-Dieter Evers

Center for Development Research (ZEF),
University of Bonn

Shahjahan H. Bhuiyan
Benefits of Social Capital. Urban Solid Waste Management in Bangladesh
Vol. 1, 2005, 288 p., 19.90 EUR, br. ISBN 3-8258-8382-5

Veronika Fuest
Demand-oriented Community Water Supply in Ghana. Policies, Practices and Outcomes
Vol. 2, 2006, 160 p., 19.90 EUR, br. ISBN 3-8258-9669-2

Anna-Katharina Hornidge
Knowledge Society. Vision and Social Construction of Reality in Germany and Singapore
Vol. 3, 2007, 200 p., 19.90 EUR, br. ISBN 978-3-8258-0701-6

Wolfram Laube
Changing Natural Resource Regimes in Northern Ghana. Actors, Structures and Institutions
Vol. 4, 2007, 392 p., 34.90 EUR, br. ISBN 978-3-8258-0641-5

Lirong Liu
Wirtschaftliche Freiheit und Wachstum. Eine international vergleichende Studie
Vol. 5, 2007, 200 p., 19.90 EUR, br. ISBN 978-3-8258-0701-6

Phuc Xuan To
Forest Property in the Vietnamese Uplands. An Ethnography of Forest Relations in Three Dao Villages
Vol. 6, 2007, 296 p., 29.90 EUR, br. ISBN 978-3-8258-0773-3

Caleb R.L. Wall, Peter P. Mollinga (Eds.)
Fieldwork in Difficult Environments. Methodology as Boundary Work in Development Research
Vol. 7, 2008, 192 p., 19.90 EUR, br. ISBN 978-3-8258-1383-3

Solvay Gerke, Hans-Dieter Evers, Anna-K. Hornidge (Eds.)
The Straits of Malacca. Knowledge and Diversity
Vol. 8, 2008, 240 p., 29.90 EUR, br. ISBN 978-3-8258-1383-3

Caleb Wall
Argorods of Western Uzbekistan. Knowledge Control and Agriculture in Khorezm
Vol. 9, 2008, 384 p., 29.90 EUR, br. ISBN 978-3-8258-1426-7

Irit Eguavoen
The Political Ecology of Household Water in Northern Ghana
Vol. 10, 2008, 328 p., 34.90 EUR, br. ISBN 978-3-8258-1613-1

Charlotte van der Schaaf
Institutional Change and Irrigation Management in Burkina Faso. Flowing Structures and Concrete Struggles
Vol. 11, 2009, 344 p., 34.90 EUR, br. ISBN 978-3-8258-1624-7

Nayeem Sultana
The Bangladeshi Diaspora in Peninsular Malaysia. Organizational Structure, Survival Strategies and Networks
Vol. 12, 2009, 368 p., 34.90 EUR, br. ISBN 978-3-8258-1629-2

Peter P. Mollinga, Anjali Bhat, Saravanan V.S. (Eds.)
When Policy Meets Reality. Political Dynamics and the Practice of Integration in Water Resources Management Reform
Vol. 13, 2010, 216 p., 29.90 EUR, br., ISBN 978-3-643-10672-8

Irit Eguavoen, Wolfram Laube (Eds.)
Negotiating Local Governance. Natural Resources Management at the Interface of Communities and the State
Vol. 14, 2010, 248 p., 29.90 EUR, br., ISBN 978-3-643-10673-5

William Tsuma
Gold Mining in Ghana. Actors, Alliances and Power
Vol. 15, 2010, 256 p., 29.90 EUR, br., ISBN 978-3-643-10811-1

Thim Ly
Planning the Lower Mekong Basin: Social Intervention in the Se San River
Vol. 16, 2010, 240 p., 29.90 EUR, br., ISBN 978-3-643-10834-0

Tatjana Bauer
The Challenge of Knowledge Sharing - Practices of the Vietnamese Science Community in Ho Chi Minh City and the Mekong Delta
Vol. 17, 2011, 304 p., 29.90 EUR, br., ISBN 978-3-643-90121-7

Pham Cong Huu
Floods and Farmers - Politics, Economics and Environmental Impacts of Dyke Construction in the Mekong Delta / Vietnam
Vol. 18, 2012, 200 p., 29.90 EUR, br., ISBN 978-3-643-90167-5

Judith Ehlert
Beautiful Floods - Environmental Knowledge and Agrarian Change in the Mekong Delta, Vietnam
Vol. 19, 2012, 256 S., 29,90 EUR, br, ISBN 978-3-643-90195-8

Nadine Reis
Tracing and Making the State - Policy practices and domestic water supply in the Mekong Delta, Vietnam
Vol. 20, 2012, 272 S., 29.90 EUR, br., ISBN 978-3-643-90196-5

Martha A. Awo
Marketing and Market Queens - A study of tomato farmers in the Upper East region of Ghana
Vol. 21, 2012, 192 S., 29.90 EUR, br., ISBN 978-3-643-90234-4

Asghar Tahmasebi
Pastoral Vulnerability to Socio-political and Climate Stresses - The Shahsevan of North Iran
Vol. 22, 2013, 192 S., 29.90 EUR, br., ISBN 978-3-643-90357-0

Anastasiya Shtaltovna
Servicing Transformation - Agricultural Service Organisations and Agrarian Change in Post-Soviet Uzbekistan
Vol. 23, 2013, 216 S., 29.90 EUR, br., ISBN 978-3-643-90358-7

Hafiz Boboyorov
Collective Identities and Patronage Networks in Southern Tajikistan
Vol. 24, 2013, 304 S., 34.90 EUR, br., ISBN 978-3-643-90382-2

Simon Benedikter
The Vietnamese Hydrocracy and the Mekong Delta. Water Resources Development from State Socialism to Bureaucratic Capitalism
Vol. 25, 2014, 330 S., 39.90 EUR, br., ISBN 978-3-643-90437-9

Sven Genschick
Aqua-`culture´. Socio-cultural peculiarities, practical senses, and missing sustainability in Pangasius aquaculture in the Mekong Delta, Vietnam.
Vol. 26, 2014, 262 S., 29.90 EUR, br., ISBN 978-3-643-90485-0

Farah Purwaningrum
Knowledge Governance in an Industrial Cluster. The Collaboration between Academia-Industry-Government in Indonesia.
Vol. 27, 2014, 296 S., 39.90 EUR, br., ISBN 978-3-643-90508-6

Panagiota Kotsila
Socio-political and Cultural Determinants of Diarrheal Disease in the Mekong Delta. From Discourse to Incidence
Vol. 28, 2014, 376 S., 39.90 EUR, br., ISBN 978-3-643-90562-8

Huynh Thi Phuong Linh
State-Society Interaction in Vietnam. The Everyday Dialogue of Local Irrigation Management in the Mekong Delta
Vol. 29, 2016, 304 S., 39.90 EUR, br., ISBN 978-3-643-90719-6

Siwei Tan
Space and Environment in the Industrialising Mekong Delta. A socio-spatial analysis of wastewater management in Vietnam
Vol. 30, 2016, 240 S., 29.90 EUR, br., ISBN 978-3-643-90746-2

http://www.lit-verlag.de/reihe/zef

zef

Center for Development Research University of Bonn

Working Paper Series

Authors: Maksud Bekchanov and Pablo Evia

Contacts: mbekchan@uni-bonn.de; pablo.evia@uni-bonn.de

Photo: Maksud Bekchanov

Published by:
Zentrum für Entwicklungsforschung (ZEF)
Center for Development Research
Genscherallee 3
D – 53113 Bonn
Germany

Phone: +49-228-73-1861
Fax: +49-228-73-1869
E-Mail: presse.zef@uni-bonn.de

www.zef.de