
Sanjib Rupakheti

Sanjib Rupakheti

Supervisor: Lars Hylander
Evaluator: Per Hultén
<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>WHO</td>
<td>World Health Organization</td>
</tr>
<tr>
<td>UNICEF</td>
<td>United Nations International Children’s Emergency Fund</td>
</tr>
<tr>
<td>MDG</td>
<td>Millennium Development Goal</td>
</tr>
<tr>
<td>HDI</td>
<td>Human Development Index</td>
</tr>
<tr>
<td>DAP</td>
<td>Diammonium Phosphate</td>
</tr>
<tr>
<td>MOP</td>
<td>Muriate of potash</td>
</tr>
<tr>
<td>VIP</td>
<td>Ventilated Improved Pit</td>
</tr>
<tr>
<td>BSP</td>
<td>Biogas Support Programme</td>
</tr>
<tr>
<td>AEPC</td>
<td>Alternative Energy Programme Centre</td>
</tr>
<tr>
<td>DWSS</td>
<td>Department of Water Supply and Sanitation</td>
</tr>
<tr>
<td>ODF</td>
<td>Open Defecation Free</td>
</tr>
<tr>
<td>JMP</td>
<td>Joint Monitoring Programme</td>
</tr>
<tr>
<td>GMAA</td>
<td>Generic Multi-Attribute Analysis</td>
</tr>
<tr>
<td>USDT</td>
<td>Urine Separating Dry Toilet</td>
</tr>
<tr>
<td>USFT</td>
<td>Urine Separating Flush toilet</td>
</tr>
<tr>
<td>CT</td>
<td>Conventional Toilet</td>
</tr>
<tr>
<td>BI</td>
<td>Biogas Integrated toilet</td>
</tr>
<tr>
<td>VDC</td>
<td>Village District Committee</td>
</tr>
<tr>
<td>CHSAC</td>
<td>Community hygiene and sanitation action committee</td>
</tr>
<tr>
<td>VWASHCC</td>
<td>Village WASH Coordination Committee</td>
</tr>
<tr>
<td>O&amp;M</td>
<td>Operation and Management Cost</td>
</tr>
<tr>
<td>RWSSP-WN</td>
<td>Rural Water Supply and Sanitation Projects in Western Nepal</td>
</tr>
<tr>
<td>DSS</td>
<td>Decision Support System</td>
</tr>
<tr>
<td>RS</td>
<td>Rupees (Nepali Currency)</td>
</tr>
</tbody>
</table>
List of Figures

Figure 1. Showing increasing Demand for Urea, Diammoniam Phosphate (DAP), and Muriate of Potash (MOP) in Metric Ton in Nepal.

Figure 2. National toilet coverage trend and required trend to achieve Millennium development Goal (MDG).

Figure 3. Showing GMAA model objective, sub-objective, and attributes.

Figure 4. Map of Nepal showing RWSSP-WN’s working district in blue colour and bigger of the RWSSP-WN district along with Kapilbastu.

Figure 5. Showing Kapilbastu District with Mahendrakot VDC in purple in North West of Map.

Figure 6. Mahendrakot VDC showing study wards marked with star.

Figure 7. Showing percentage of Respondents known to Eco-san.

Figure 8. Showing Nitrogen and Phosphorus demand and Possible Extraction from USFT and USDT systems.

Figure 9. Overall utility ranking of sanitation alternatives.

Figure 10. Showing alternatives ranking based on Technical aspect.

Figure 11. Showing alternatives ranking based on Social aspect.

Figure 12. Showing alternatives ranking based on Environmental aspect.

Figure 13. Showing alternatives ranking based on Economical aspect.

Figure 14. Showing subtracted attribute value for technological aspects of BI and Conventional toilet system.

Figure 15. Showing subtracted attribute value for cultural taboos of BI and Conventional toilet system.

Figure 16. Showing subtracted attribute value for economic and environmental aspects of BI and Conventional toilet system.

Figure 17. Comparison of technical attributes between Conventional toilet and USDT.

Figure 18. Comparison of social attributes between Conventional toilet and USDT.

Figure 19. Circular flow of nutrients with the use of Ecological Sanitation.

Figure 20. A composting toilet with liquid separation.

Figure 21. Liquid separation composting toilet.

Figure 22. The ‘Carousel’ composting toilet, Norway.

Figure 23. General view of sanitation related stakeholders from government level to local User level along with the various aspects of toilet system. Bold objectives are crucial to change user’s motives to bring sustainable toilet system.
Contents

1. Introduction ........................................................................................................................................... 1
   1.1. Sanitation ....................................................................................................................................... 1

   1.2. Nepal ............................................................................................................................................... 1
      1.2.1. Sanitation status of Nepal ........................................................................................................ 1
      1.2.2. Sanitation and health ................................................................................................................ 1
      1.2.3. Sanitation and agriculture ........................................................................................................ 2
      1.2.4. Sanitation and urbanization ...................................................................................................... 2

   1.3. Types of sanitation alternatives ...................................................................................................... 3

   1.4. Environment friendly sanitation practices ....................................................................................... 4
      1.4.1. Biogas integrated toilets ........................................................................................................... 4
      1.4.2. History on the use of human waste/dry toilets............................................................................ 4
      1.4.3. New toilet technologies as dry toilets ...................................................................................... 4

   1.5. Government goal on sanitation ..................................................................................................... 4
      1.5.1. Two phases of achieving government goal ............................................................................... 5
      1.5.2. Expected upshot from sanitation goal ....................................................................................... 6

2. Objective of the study .......................................................................................................................... 6

3. Research methodology ......................................................................................................................... 7
   3.1. Application of Generic Multi-Attribute Analysis (GMAA) ............................................................... 7
      3.1.1. Attributes .................................................................................................................................. 7
         3.1.1.1. Social and technological aspects ......................................................................................... 8
         3.1.1.2. Environmental aspect of sanitation alternative .................................................................. 12
         3.1.1.3. Economic aspect of sanitation alternatives ....................................................................... 13
      3.2. Study area .................................................................................................................................... 17
      3.3. Household questionnaire survey .................................................................................................. 20
      3.4. Interaction with locals volunteers on eco-sanitation .................................................................... 21

   3.5. Sanitation Alternatives .................................................................................................................. 22
      3.5.1. Urine Separating Flush Toilet ................................................................................................. 22
      3.5.2. Urine Separating Dry Toilet (USDT) ...................................................................................... 23
      3.5.3. Biogas Integrated Toilet (BI) .................................................................................................. 24
      3.5.4. Conventional Toilet (CT) ....................................................................................................... 25

4. Results and findings ............................................................................................................................. 26
   4.1. Survey findings ................................................................................................................................. 26
   4.2. GMAA results .................................................................................................................................. 27
      4.2.1. Alternatives ranking with utilities ............................................................................................. 27
4.3. Optimal solution for different objective aspect ................................................................. 27
  4.3.1. Technical aspect ............................................................................................................ 27
  4.3.2. Social aspect ................................................................................................................ 28
  4.3.3. Environmental aspect .................................................................................................. 28
  4.3.4. Economical aspect ..................................................................................................... 28

5. Interpretation of the result .................................................................................................. 30
  5.1. BI and conventional toilet systems .................................................................................. 30
  5.2. Comparison between USDT and CT based on technological aspects .............................. 31

6. Discussion .......................................................................................................................... 33
  6.1. Survey result .................................................................................................................... 33
  6.2. GMAA result ................................................................................................................... 33
  6.3. Sustainable sanitation system .......................................................................................... 33
  6.4. Ecological Sanitation and its Promotion in rural areas .................................................... 35

7. Conclusion .......................................................................................................................... 39

Acknowledgement .................................................................................................................. 40

Bibliography ............................................................................................................................ 41

Annex ....................................................................................................................................... 45
  Annex 1 ................................................................................................................................. 45
    Weightage given to the objective, sub-objective, and attributes on GMAA model ............... 45
  Annex 2 .................................................................................................................................... 46
    Questionnaire Model .......................................................................................................... 46
Evaluation of rural sanitation alternatives in Nepal using Decision Support System (DSS) approach

SANJIB RUPAKHETI


Abstract: A society’s health depends on the access to proper and hygiene sanitation. Half of the population still do not have access to proper sanitation in Nepal; therefore government and non-government organizations are facilitating sanitation access to all the population. Decades ago, open defecation and pit latrines toilet were the only options as sanitation system to the people. But now, various types of toilets system known as dry toilets, septic tanks, centralized sewerage system and biogas integrated toilets are available. Therefore, existing toilet system in rural areas of Nepal needs to be evaluated with respect to environment and long term sustainability. Aim of this study is to find the appropriate toilet system for rural areas of Nepal. This study also discusses how that appropriate toilet system can be promoted based on current scenarios from government level to local level.

Generic Multi-Attribute Analysis (GMAA) is used as a decision support tools to evaluate available various toilet alternatives. For which a rural area from Nepal is chosen as study area. GMAA helps in evaluating all the toilet system based on social, technological, environmental and economical aspects. Interpretation between the toilet systems can be made easily with the help of GMAA results. Field questionnaire survey was also carried out in the study area to know user’s understanding of toilet alternatives.

Every toilet systems have pro and cons based on different social, technological, environmental and economical aspects. It was found that pit latrines toilet systems are mostly practiced in the rural areas of Nepal. User prefers pit latrines because of its social accepted character and technologically easy in using it. Biogas integrated toilet system came as optimal toilet system though not accessible to all household. It was found that urine and faeces separating toilets are environmentally and economically beneficial. The thesis concludes that appropriate toilet system which is sustainable must be promoted while increasing toilet coverage in Nepal. Urine and faeces separating toilet is found to be appropriate and need to be incorporated in the government goal of increasing toilet coverage.

Keywords: rural toilet systems, sustainability, biogas toilet, urine separating flush toilet, urine separating dry toilet,

Sanjib Rupakheti, Department of Earth Sciences, Uppsala University, Villagägen 16, SE- 752 36 Uppsala, Sweden
Evaluation of Rural sanitation alternatives in Nepal Using Decision Support System (DSS) Approach

SANJIB RUPAKHETI


Summary: Nepal is a country where half of the population do not have sanitation access. However, the number of people having access to toilet system is increasing. Yet, the environmental concern on the use of toilet is not common. The use of human waste is beneficial to the rural people if it is used in field rather dumping it in the ground. A toilet system needs to be recognized that guarantees the use of human waste and increases rural people’s hygiene behaviour.

Valuable nutrients resources that are available in the human wastes must return to the field to help grow other food. Certainly, a toilet system can be a best toilet system socially or economically or environmentally. but considering all environmental, economical, social and technological aspects could give a sustainable toilet system that promises the long term benefit to society.

In Nepal, government of Nepal and other private organization are targeting to reach the total sanitation access to all the people by 2017. Cities population have access to developed sanitation practices as septic tank but rural people are used to with open defecation or simply constructed pit latrines toilet. Government’s effort in increasing toilet access to people, focus is only given to increasing sanitation coverage.

Now, various types of toilet systems are available in rural areas of Nepal. Biogas integrated toilet system is also a newly appreciated toilet system for it’s environmentally features. However, easiest form of toilet system for rural people are digging a hole in ground and use it to collect human waste, which is not environmental friendly and inappropriate toilet system economically as well. Biogas toilet system is a promising toilet system environmentally and economically but insufficient resources availability like livestock and investment are obstacle in promoting such environment friendly toilet system. In History, few cultures had practiced urine and faeces separating toilet system which is no longer in use and the motive for such toilet system was to increase agricultural yield by using it as fertilizer.

The GMAA study showed that, for a chosen study area, biogas integrated toilet system is the optimal toilet system however; collecting human waste in pit hole is the most common and socially accepted. Analysis showed that the nutrients recovery from urine and faeces separating toilet gives greater economical benefit to the people than any other toilet system. Environmental pollution is also less than any other toilet system. In the study, evaluation between the toilet systems in the study helped in finding a suitable toilet system that is sustainable. A short description of all the stakeholders associated with the toilet system also explains that who should be responsible in promoting sustainable toilet system. The Study was carried in rural areas of Nepal and GMAA result was taken as the general result for all rural areas of Nepal.

Keywords: sanitation alternatives, biogas toilet, conventional toilet, rural Nepal, sustainability

Sanjib Rupakheti, Department of Earth Sciences, Uppsala University, Villagägen 16, SE- 752 36 Uppsala, Sweden
1. Introduction

1.1. Sanitation
Sanitation is an issue for every household and community that plays a direct role in public health to the hygienic conditions of that community. Therefore, sanitation is considered as a serious issue in a small community to global level. WHO/UNICEF (2010) defines sanitation as the provision of facilities and services for the safe disposal of the human excreta. Hygiene access to sanitation is believed to provide significant positive impacts on health both in households and across communities while maintaining hygienic conditions (Joint Monitoring Programme, 2010). Sanitation is not important only for some individual, or group or some communities; every human is attached to the sanitation and its right to have sustainable sanitation access.

Globally, 63% of the world population only had access to safe sanitation by 2010 leaving 2.5 billion people without sanitation access (Water and Sanitation guide, 2012). Since, sanitation determines whether the community is healthy or not, remaining 37% world population without sanitation access must be able to access improved sanitation in order to raise their welfare and health. Therefore, Millennium Development Goal (MDG) was formed to provide sanitation access to all the human population worldwide. As per the MDG target set by The United Nations General Assembly, the world population having no access to sanitation practices should be able to have access to sustainable sanitation access by 2015 (Joint Monitoring Programme, 2010).

1.2. Nepal
Nepal is a landlocked country with 147, 181 sq. Km area. The country is surrounded by India in the east, west and south, and China in the North. With population of around 29.4 million (2011) Nepal stands at 138 Human Development Index (HDI) according to the Human Development Report 2010, ranking where the lowest is 169 (Rai, A., 2011). Nepal has a varied geography from mountains including eight of the top tallest mountains on north and plain land with forest on the south.

1.2.1. Sanitation status of Nepal
Sanitation, health, agriculture are the crucial aspects in rural, urban communities in providing the better living condition. Among them, Sanitation is one of the first major issues for healthy community. The life expectancy of human has drastically increased in last half centuries because of the behavioural change in managing and handling human waste in sanitation. Centralized sanitation system in urban areas as sewerage system is mostly appreciated sanitation system developed in last centuries. However, the centralized sanitation system is polluting the environment in bigger scale. In context of rural areas, where sanitation facilities are not accessible, open defecation, direct pit latrines are practiced as an alternative. The importance of sanitation in Nepal was actually recognized with the addition of a sanitation related target to the Millennium Development Goals (MDGs) following the Johannesburg Summit on Sustainable Development in 2002 (Shrestha, Tayler & Scott, 2005).

In a published work from Department of Water Supply and Sewerage, Nepal, the national sanitation coverage is only 43% by 2010 which is even lower in rural areas where majority of the people (80%) resides. And there is wide gap of sanitation coverage between rural (37%) and urban (78%). The sanitation coverage in mountain, hill and terrain are 52%, 42.3% and 35.3% respectively. More than half of the population yet lack sanitation access. Therefore, a goal was made to provide sanitation access to all the population by 2017 by Government of Nepal and other foreign organization. (Sanitation and Hygiene Master Plan, 2011)

1.2.2. Sanitation and health
Low sanitation coverage in country has been the major cause for higher morbidity in Nepal. Water and sanitation related disease are still remain at the top ten causes of morbidity and diarrhoeal diseases is the second largest reason among infant mortality (Rai Amrit, 2011). Most of the diseases that accounts of 80%, are somehow associated to the water and sanitation related causes which is major reason for almost 13,000 child deaths each year from diarrhoeal disease such as dysentery, jaundice, typhoid, and cholera (Ministry of Physical Planning and works, Nepal, 2008).

1 http://www.economywatch.com/economic-statistics/country/Nepal/
2 Human Development Index (HDI) a method to measure development of a country based on life expectancy, educational attainment, and per capita income. 1st ranking is considered as better in all aspects of human life.
Unplanned sanitation approaches and unaware society where human waste is polluting the ground water, surface water, and river. The use of conventional type of toilets with pit whole because of the easy dumping method in ground is allowing the human faeces and urine to mix with ground and surface water and at the same time, majority (90%) of the population living in the plain land of Nepal depends on ground water for their daily use (Yadav, Dhuldhaj, Mohan & Singh, 2011) This fact also supports that public health is also vulnerable because of the ground water contamination from improper sanitation where dumping in ground which is common in normal sanitation practice. The varied steep geography has also facilitated the waste to flow and mix with water resources easily and downstream users are more vulnerable to diseases.

1.2.3. Sanitation and agriculture

The need for fertilizers in agriculture actually arises from the linear flow of nutrients in the ecosystem. Quantity of nutrients that goes into human body as food, usually end at the sewerage system or to the ground and deficiency of nutrients in the field needed for the plant growth are fulfilled with the use of chemical fertilizers. If all the nutrients available in the human waste are recycled and used in field, such sanitation would provide solution to the increasing demand for chemical fertilizers (DWC, 2013). Sanitation and agriculture are interlinked two different aspects where nutrients flow from agriculture to sanitation aspects in general. This is the reason chemical fertilizers are used in agriculture.

Nepal has agriculture based economy however; the numbers of farmers are decreasing because of urbanization. Consequently, the need for food for the growing population is on the rise and the need for chemical fertilizer is also growing. Currently, chemical fertilizers and locally made manure are the sources to harvest food. Given Figure 1 shows that demand for three basic fertilizers commonly used in Nepal are growing and the need for fertilizer is pervasive that the demand has to be fulfilled either by importing or by producing within the country.

![Diagramrubrik](Diagramrubrik)

**Figure 1.** Showing increasing Demand for Urea, Diammonium Phosphate (DAP), and Muriate of Potash (MOP) in Metric Ton in Nepal.


1.2.4. Sanitation and urbanization

In Nepal, 15% of total population is the urban population living in 58 communities in urban areas however; the urban population is increasing rapidly at 6.6% per annum. Sadly, only three quarters of the urban population have access to proper sanitation facilities. Onsite sanitation systems, such as septic tanks, pit hole toilet are practiced in large number because sewerage sanitation system is not available to all the urban population. However, study has showed that such septic tanks systems are not a viable option especially for densely populated core town areas (Nycander, Cross & Damhaug, 2011).

Table 1 shows that, in Urban areas, only 16.7% of urban population have access to sewerage sanitation system and almost 50% urban population are using wet toilet which are mostly pour-flush toilet, flush toilet with septic tank. Significant population are still using unimproved open defecation practice. By the time of 2008, 17.5% of the total population was in urban areas (WHO/UNICEF, 2012).
Table. 1. Showing different practiced sanitation systems in percentage for Urban and Rural areas of Nepal in 2008.


<table>
<thead>
<tr>
<th>Original Denomination</th>
<th>Percentage of Urban and Rural population (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Urban (%)</td>
</tr>
<tr>
<td>Sewerage</td>
<td>16.7</td>
</tr>
<tr>
<td>Wet toilet</td>
<td>50.0</td>
</tr>
<tr>
<td>Pit toilet</td>
<td>12.0</td>
</tr>
<tr>
<td>Unimproved OD</td>
<td>20.3</td>
</tr>
</tbody>
</table>

Sewerage systems, often combined with storm water drainage systems, exist in a number of urban areas. However, their coverage is limited and final treatment of the sewage is often inadequate, if not totally nonexistent. Inadequate treatment plant has resulted in environmental deterioration (Nycander, Cross & Damhaug, 2011). Loss of nutrients every day into the storm drainage or centralized system and then into the river would make nutrients to accumulate in the river or in a sea or in a lake causing eutrophication. These are the few drawbacks of the centralized sewerage system.

In centralised sanitation system, individual sanitation problem are gathered at a central point and waste management is done at one place. There are challenges in providing appropriate sanitation alternative for growing urban population that requires considerate amount of investment to provide the centralised sanitation where operation and maintenance cost is high. However, the need to assure urban population of safest public health, study of cost effective sanitation technologies or cost sharing mechanisms is majorly a way out for a sustainable sanitation practice (Sanitation and Hygiene Master Plan, 2011).

1.3. Types of sanitation alternatives

A toilet system that hygienically separates the human waste faeces and excreta from human is considered as the improved sanitation facility. Basically, human waste is taken as the source of diseases therefore, hygiene approach in managing human waste is supposed to be a main function of improved sanitation facility (WHO/UNICEF, 2012). In Nepal, while facilitating sanitation access, such improved sanitation toilet is generally understood by permanent toilet. Impermanent toilets are constructed only for short period to end open defecation. Having a sanitation access means the safest management of human waste in order to prevent water contamination and diseases associated with poor sanitation.

Sanitation and Hygiene Master Plan (2011), Nepal has classified improved sanitation facility in to four basic types which is given below.

- Flush or pour-flush to
  - Piped sewer system
  - Septic tank
  - Pit latrine
- Ventilated Improved Pit (VIP) latrine
- Pit toilet with slab and lid
- Composting toilet (eco-san)

Source: (Sanitation and Hygiene Master Plan, 2011)

All these above mentioned sanitation systems are practiced in Nepal. Basically, pit latrine are mostly used in rural areas which are temporary type and after that single or double pit pour flush toilets are second most used

---

3 The process by which a body of water acquires a high concentration of nutrients, especially phosphates and nitrates.
(ENPHO, 2006). Despite those sanitation practices defined by WHO/UNICEF, biogas integrated toilet and urine separating dry toilet (USDT) and urine separating flush toilet (USFT) are also practiced however, these toilets are very new concept in Nepal and famous for its environmental friendly approaches. In contrast, since government has not been able to provide proper managed sewerage system, septic tank systems are practiced in the urban areas. Accordingly, environmental degradation as water, soil and air are endlessly occurring.

1.4. Environment friendly sanitation practices

1.4.1. Biogas integrated toilets

Biogas integrated toilet is also called the source of renewable energy. Sanitation can be linked to biogas production though human waste from sanitation itself is not sufficient to provide the energy in household purpose (Forte, 2011). Among all the sanitation alternatives, biogas integrated toilet is more expensive because of the concrete structure and appliances required. Excessive need of livestock dung and heavy monetary investment makes the biogas integrated toilets out of the reach for the people who are financially unstable.

The biogas was first installed in July 1992 when the Biogas Support Programme (BSP) initiated it. BSP is organised by Alternative Energy Program Centre (AEPC) under the ministry of Environment. After 20 years of work in Nepal from BSP, household size biogas plants with integrated toilet system are taken as successful.

Those organization heavily subsidized biogas integrated toilet where livestock waste are also available; which was part of promotion plan in Nepal (Forte, 2011). Data are not available on how much success the organizations has gotten in promoting biogas integrated toilet in Nepal.

1.4.2. History on the use of human waste/dry toilets

Some of the inhabitants used human waste as fertilizer in agriculture field and the toilets were constructed in such a way that human waste would easily be collected to make it fertilizer. Human waste is used to be considered as valuable resources in past. For example the Newars who is traditional inhabitants of the capital city Kathmandu and Sherpas from the mountainous region used to collect and recycle human waste (Sherpa is a ethnic group of people from mountainous region and Newar from Capital city Kathmandu of Nepal). Many households also used to sell their waste or human waste to farmers. They used to mix human waste with other organic waste from the household and add ashes not to make it foul smelling. However, increased modernisation is taken as the reason why such sanitation system is no longer practiced and disappeared in Kathmandu valley. Sherpas usually build two types of composting toilets, called temporary and permanent, and based on the family’s economic status. And that structure could be built inside the building or nearby. Just as modernisation was taken as the reason for disappearance of such toilet in Newar culture in Kathmandu valley, increased tourism in the mountainous region is considered as the reason for the disappearance of such traditional composting toilets. Though, few such toilets are still available in some places which are untouched by trekker’s route in the rural mountainous area. (Pradhan, pp. 7-11, 2008)

1.4.3. New toilet technologies as dry toilets

Eco-san came as a new sanitation alternative in Nepal in 2000, when one official first attended training on dry toilet in Sweden. Later, he built dry toilet in his own home and in office and helped sharing information with his colleagues. This incident was followed by another training attended by Mr. Nawal Kishor Mishra, chief sanitation section Department of Water Supply and Sanitation (DWSS) in a conference in Germany and he practiced the dry toilet technology in a village as a pilot experiment. Similarly, another initiation by DWSS/WHO, pilot eco-san program in Lalitpur district was carried which is the first built eco-san toilet in Nepal and publicized as sanitation system with economic benefits. In the last decade, around 2000 dry toilets were constructed all over the Nepal. (Khatri, 2012,)

1.5. Government goal on sanitation

So as to uplift the public health, the government has formulated some master plan as goal to achieve which is to increase the sanitation coverage in country by the end of 2017 which is shown in table 2. The goal comprises of providing more hygiene environmental friendly sanitation for people. Basically, the changes in behaviour expected to be hygiene and sustainable so that that the toilet system is practiced properly. (Adhikari, 2012)
Figure 2 below shows the current rate in which the toilet coverage is growing in Nepal and the red line represents the extended future trend for toilet coverage. To achieve the global goal of providing sanitation access to half of the population who do not have access to sanitation currently, Figure 2 illustrates that the current trend is not enough to achieve the global goal on time. Therefore, additional work has to be done to push forward the toilet coverage rate.

1.5.1. Two phases of achieving government goal

Government’s first focus first is to make communities Open Defecation Free (ODF)\(^4\) to reach the total sanitation coverage goal. While declaring an area ODF, users do not necessarily have to have access to improved sanitation facilities. However, users might be practicing direct pit latrine which are temporary types and their purpose is to end the open defecation. Later on, improved sanitation facilities are promoted among all the users with more concrete plans and activities from government’s side (Sanitation and Hygiene Master Plan, 2011). As per the types of sanitation facilities that Joint Monitoring Programme between WHO and UNICEF has classified, government and other supporting organizations focus mainly on conventional practices but very little effort has been made in the field of other potential toilet facilities.

Government is using total sanitation approach to achieve total sanitation coverage in country, which follows two phases; ODF situation and Total Sanitized Post-ODF Situation. Generally, ODF is the first goal for any governmental or non-governmental organisation in accessing toilet; therefore ODF is declared only when no one defecate openly and all the household have access to improved sanitation facilities. Declaring ODF is the first phase of achieving global goal and it is called ODF situation. Secondly, Total Sanitized Post-ODF Situation is

---

\(^4\) In Nepal, half of the population do not have sanitation access and these people defecate openly. Therefore, when this open defecation is completely stopped, then we call the place as open defecation free (ODF) declared area.
achieved only after declaring ODF with maintained hygiene behaviour in their daily life. (Sanitation and Hygiene Master Plan, 2011)

1.5.2. Expected upshot from sanitation goal
Water and sanitation policies formulated in National Urban Water Supply and Sanitation Policy (2011) states that the entire sanitation alternative should possess terminologies like public health, economic growth, effective and accountable urban water supply and sanitation sector. Since the time to achieve MDG goal by 2017 is nearing, the rush to goal has prevented possible improvement in the conventional alternatives that could have brought environmental friendly alternatives. However, the ecological sanitation is a new and scientifically accepted development in the sanitation technology field. Therefore, dry operation of human waste has only been exercised in some extent. (Sanitation and Hygiene Master Plan, 2011)

Sanitation alternatives are expected to make improvement on terminologies public health, economic growth, social inclusion, protecting and optimising investments, environmental protection, and an efficient, effective and accountable urban water supply and sanitation sector (Sanitation and Hygiene Master Plan, 2011). However, the master plan does not state that those explained indicators makes a sanitation alternative sustainable or not.

There is no any assessment has been made yet to check either any sanitation alternative possess any of the explained terminologies. Therefore, an assessment must be carried out to measure the weight of the sanitation alternative with the help of above terminologies. For example, the sewerage sanitation system that heavily depends on the water resource which ends up as a waste and nutrients value of the human waste; both do not address the above terminologies. Therefore, a detail examination over the alternatives in terms of above stated aspects need to be done.

The thesis will find the optimal sanitation alternative for the study area and evaluation will be done with one another. Given government terminologies which a sanitation alternative should posses will be evaluated so as to know either government goal are really fulfilling or not.

2. Objective of the study
More than half of the population in Nepal do not have access to sanitation. Open defecation is the only sanitation alternative for those who does not have sanitation access. Environmental degradation and public health are the major concerns associated with sanitation. The thesis will examine how the government and other organization are dealing with environment and public health while increasing the toilet coverage in Nepal. It is important to evaluate what types of toilet facilities are being provided in order to make societies sustainable. Therefore, the thesis primarily includes evaluation and analysis of various toilet facilities with the use of DSS tools.

In this thesis, various types of toilet facilities that exist in rural areas of Nepal are discovered and evaluation between these alternatives will be carried out with the help of DSS tool. DSS tool will act as a methodology where the assessment between alternatives is basically made on the basis of social, economical, technological and environmental aspects. Especially, the thesis will possibly give answers to why a specific toilet facility is more practiced in community; which is the sustainable alternative to society; how can a sustainable toilet facility be promoted in present scenarios.

Hence, objective of the study are:

1. To find the optimal sanitation alternative in a study area chosen from rural areas of Nepal, according to present social-economic scenarios by using GMAA approach.
2. Evaluation and assessment of sanitation alternatives available in the study area.
3. Finding a sustainable sanitation facility for the rural people.
4. How a sustainable sanitation can be promoted in present scenarios.
3. Research methodology

3.1. Application of Generic Multi-Attribute Analysis (GMAA)

Generic Multi-Attribute Analysis (GMAA) will be used as a Decision Support System (DSS) tool to access the optimal sanitation alternative and to evaluate the various sanitation alternatives in the study area. Application of GMAA involves the construction of a model that is supported by social, economical, technological, and environmental aspects called foundation for sustainability which is shown in Figure 3. Furthermore, several attributes related to those objective foundations, will also be evaluated during the analysis of the GMAA result.

Objective in the GMAA model brings in four sanitation alternatives. Urine Separating Flush Toilet (USFT), Urine Separating Dry Toilet (USDT), Biogas Integrated (BI) toilet, and Conventional Toilet (CT) are mostly used sanitation alternative in the study area. Basically, four foundation of sustainability economical, social, and environmental along with technological aspects were considered as the sub-objective. Sub-objectives are further categorized with related terminologies called attributes on the right of the model shown in figure below.

![Figure 3. Showing GMAA model objective, sub-objective, and attributes.](image)

3.1.1. Attributes

Environmental and Economical aspects of the sanitation alternative were incorporated based on the facts and measurement which will be elaborated below. Other objective aspects like technical and social were measured based on the people’s perception. Most of the utility pattern was drawn on assumption that until half of the user prefer certain toilet system, the utility for that specific toilet will not be higher than 0.25 as shown in figures below.
### Technical Aspect

#### Recycling method

Method of handling and managing human waste for each alternative is different. Handling of urine and faeces in both USFT and USDT systems are different. In USDT, Urine and faeces are separated and stored in a proper way until it becomes ready to use as fertilizer. However, in USFT, only urine is collected for agricultural purpose. Whereas, in conventional toilet system, urine and faeces are collected in pit or in septic tank and dump it openly without any environmental consideration. However, in BI toilet, both urine and faeces are processed in a chamber to produce biogas and sludge as end product from chamber. Based on the user’s preference on recycling methods, utility for the alternatives will be measured.

#### Storage capacity

Each alternative requires space in collecting and handling human waste. While viewing the space needed for each alternative, conventional toilet are more preferred by users than BI and then USFT and USDT. It seems to users that, storing urine and faeces are problematic whereas, in conventional system, users do not have to think of space once the toilet is built. Based on the users preference from survey, subjective scale was created for storage capacity.

#### Equipment Accessibility

Equipment used in different sanitation alternatives is different. Conventional latrines are locally built and equipments like Concrete slab with sitting pan, concrete ring, brick, or local wooden material etc are locally developed. BI toilet equipments are available only in the market which is 4-5 Km far away from the study area. Similarly, equipments for USFT and USDT are not easily available in the nearest market. One has to travel more than 10 Km to get the urine separating toilets. Utility plot is therefore created in monotonically decreasing order as the distance increases in accessing equipments.

#### Gender Friendly Technology

Conventional and BI toilets are not much different in terms of gender friendly however, in USFT, women are having difficulties in collecting urine using cone or collecting jar whereas men were found collecting urine easily. Since, all alternatives have some potential in terms of gender friendly technologies; utility was drawn based on the people preference over alternatives’ gender friendliness.
Sanitation alternative must also be usable for user of all age. Usually, such term is not taken as serious matter in rural areas while choosing a sanitation alternative because of the prior need of toilet first. When Users were introduced with the commode system USDT during the questionnaire, users showed their keen interest in commode system because of its friendliness character. Utility was drawn assuming that until and unless one third of the population admits that one alternative is user friendly for people of all age, the utility will not surpass 25%.

Extracted fertilizers from human waste need to be used in a proper way. In BI, the end product are collected in a pit and after when it gets dried, it is used in farm land. Similarly, the urine and faeces collected from USFT and USDT must also be used in field in a proper way. Urine sometimes cause more harm to the plants if it is added in large quantity and some such cases were found in the study area. Therefore, knowledge on executing end product form toilet also plays a role in choosing the toilet system. Comparatively, users are more accustomed with conventional and BI end product in executing it. Subjective scale was plotted from the user’s preference.

User’s preference on sanitation alternative depends also on how the working stakeholders in promoting sanitation convey the message. Usually, the Village District Committee (VDC), Community hygiene and sanitation action committee (CHASAC) as stakeholders only focus to increase the toilet coverage with the conventional toilet type. Hence, it is helping in promoting conventional toilet system. Since, these stakeholders are the local people; they lack the knowledge about other types of toilet.

Existing stakeholders act as catalyst in promoting sanitation alternative. Therefore, subjective scale was drawn based on the number of stakeholders.
available for specific alternatives.

**Market**

This attribute measures the possible economic activities of human waste as fertilizer. Buying and selling of such fertilizer from different alternatives were measured for each alternative in study area. In the study area, human waste as fertilizer from BI toilet system is shared in the communities for money. Generally, user do not sell their fertilizer because they always lack fertilizer in their field and they buy chemical fertilizer from maker to fulfil the demand. Urine and faeces are not used as commodities because USFT and USDT is new to users. Lack of knowledge on the use of urine and faeces would be the reason users buy chemical fertilizers. Therefore, constructed subjective scale was drawn based on the economic activities of human waste done by users from the sanitation system they used in the study area.

**Social Aspects**

**Infectious Susceptibility**

Some alternative system might be more susceptible to infection compared to other. For example, User may have perceived that flushing of urine and faeces cause more benefit to health rather than using it to produce biogas or to make fertilizer by separating urine and faeces. Because, USFT, USDT and BI requires the handling of human waste. Therefore, this attribute will explain which toilet system is prone to infection while handling and managing of waste. Utility was drawn based on the assumption that the utility will get higher value only when half of the user believes that the certain alternative is not infectious to health.

**Hygiene Sanitation**

Hygiene sanitation here signifies the pre-condition that is usually seen in the toilet. Some toilet system might be hygiene and unhygienic aesthetically. For example, BI toilet system does not look hygienic aesthetically. In similar way, user’s perception on different sanitation alternatives as hygienic and unhygienic was measured with Hygiene sanitation attribute.

**Drudgery**

Drudgery means the hard monotonous routine work necessary to carry out in the toilet system. In BI system, usually, user has to mix the human waste and other livestock dung with water. If the water is scarce, user may have to fetch the water from the distance source. In USDT, collection of ashes, urine restoration, and faeces collection may take several hours. Though, water fetching is common work for all alternatives, other necessary work associated with toilet system may play a role in
user’s choices for toilet alternative.

In Nepal, women are supposed to do most of the household work. Therefore, women are also more inclined to work in toilet system. Based on the type of toilet system, women’s role also varies and some toilet system could play a great role in empowering women. In USDT and BI, if women’s involvement is considered turning human waste to fertilizer, which could bring a change in women status in male dominated rural areas.

User’s preference over toilet system also depends on what is common used in society. Practicing the common toilet system make user believe that they are socially accepted. The number of different toilet system existing in the study area was incorporated in model as utility.

Attitude or intention generally defines the positive or negative feelings about the object. Here, user’s attitude towards urine and faeces are measured. Since, all the toilet system require handling and managing of human waste, user’s attitude towards human waste play a role in choosing the toilet system. Positive attitude toward urine and faeces would result the use of USFT and USDT system. Utility graph was plotted monotonically decreasing order where toilet system gets higher utility value for low number of people whose attitude toward a specific system is negative.

Behaviour

User’s intention and behaviour differ in the action. Intention was measured in the attitude attribute, though user’s behaviour towards urine and faeces is measured here in behavioural attribute that affect user’s choice. Since, survey has shown that most of the users were known to fact that human waste are valuable resources as fertilizer which acts as their intention, but users behaviour do not support their intentions. Interestingly, some users found to be
using the waste from filled pit after a year as resources in conventional type toilet without any environmental consideration. Behavioural measurement was done with the survey questionnaire based on the user’s behaviour that favours certain alternative.

Motivation

Motives are always there in choosing and practicing a specific alternative. For example, some user prefers BI toilet system because it is aesthetic, comfortable, source of energy for them. Similarly, environmental concern could have also been a motive in practicing USFT for some users because it provides cooking fuels which is pollution free, serve comfort by providing fuel as alternative to fuel woods. Motivation attribute will deal user’s motive towards different sanitation alternative.

3.1.1.2. Environmental aspect of sanitation alternative

3.1.1.2.1. Water pollution

An experiment carried out in Uganda on September and November, 2007 resembles the same case with the study chosen for this thesis. In the experiment, the ground water from 5 different springs and 10 shallow wells were analysed to check the water quality upon which rural people were dependent on for their daily use. Most of the people were using pit latrine sanitation system and water resources for that population are also spring sources and shallow depth pumping system; and the results came up with the contamination of faecal bacteria in 5 sources (Kabongo & Kabiswa, 2008). Which shows that, ground water is more vulnerable to bacterial contamination if proper sanitation is not adopted. Therefore, while comparing to our study area where all population depends on the spring source and the shallow depth pumping ground water; use of the pit latrine without any barrier to the ground has opened up the chances of ground water pollution. Hence, pit latrine system or urine separating flush toilet; both are water polluter in same level. However, in biogas integrated toilet, the end product as sludge barely mix to the surface water only during the rainy season and almost no significant flow to the ground water probable pollution to ground water happens during rainy season for 4 months therefore, the pollution was assumed to be around 40 compared to the pollution from conventional. Since, in USDT, urine and faeces are handled without any contamination to ground or surface water, water pollution is zero from it. However, in USFT, urine is collected but faecal matter still could pollute the water sources as in conventional toilet system. Therefore, conventional toilet and USFT are considered to have equal impact on water.

<table>
<thead>
<tr>
<th>Alternatives</th>
<th>USFT</th>
<th>USDT</th>
<th>BI</th>
<th>Conventional</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water pollution</td>
<td>100</td>
<td>0</td>
<td>40</td>
<td>100</td>
</tr>
</tbody>
</table>

*Table. 3. Constructed Probable Water pollution from sanitation alternatives*

*Source: (Hylander, 2006)*
Water pollution utility is higher if water pollution is less as measured above. Since, pollution from conventional toilet is 100, the utility is 0. The utility function works for other alternative in similar way.

3.1.1.2.2 Air pollution

Air pollution from an individual household’s sanitation system seems insignificant but the accumulated air pollution from all the sanitation systems worldwide has a significant contribution to the air pollution. Usually, dry toilet does not pollute air if the system is managed properly in anaerobic condition. Because, faeces matter under anaerobic condition, loses it’s 90% of weight and become the organic matter ready to use as fertiliser.

Emission of gasses from each and every step in all alternatives can also be felt by inspection. For example, in conventional toilets, foul smell which can easily be felt unless the toilet is built with the use of a ventilated pipe for the safe passage for gasses to the atmosphere. Urine separating flush toilet is similar to the conventional because of the flush system for faeces. Urine separating dry toilet is the only alternative that is free from the emission. A data shows CO2 emission from different sanitation system as shown in table 4 below.

<table>
<thead>
<tr>
<th>Alternative</th>
<th>USFT</th>
<th>USDT</th>
<th>BI</th>
<th>Conventional</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO2</td>
<td>69</td>
<td>27</td>
<td>29</td>
<td>100</td>
</tr>
</tbody>
</table>

Table 4. CO2 emission of sanitation option (%) taking conventional as baseline measurement

Source: (Khatri, 2002)

More CO2 releases by a toilet system means less utility of a specific sanitation system. Hence, utility was drawn as monotonically decreasing in order.

3.1.1.3 Economic aspect of sanitation alternatives

3.1.1.3.1 Money Benefit

Sanitation alternatives do posses economic benefit if we relate it to the nutrient extraction. Since large amount of money is spent every year on chemical fertilizer DAP, Potash, Urea, Phosphate etc, extraction of nutrients from human waste can be a solution to it. Scientific name for these fertilizers are Urea and dia-Ammonium Phosphate (DAP), Muriate of Potash (MOP) labelled with (46-0-0), (18-20-0), (60%) (Reef Wise Farming, 2012) and these fertilizers are easily available in the near market in the study area. Since, the human waste contains nutrients that can be used as fertilizers and it has potential remark to replace chemical fertilizer.
Nutrients extraction from the sanitation alternatives is calculated and measured with the current demand to measure the monetary value of each sanitation alternative. Quantity measurement of the nutrients can be done in USFT and USD T in terms of nutrients available in human waste, however, the nutrient contents in the end product from BI toilet would contain the nutrients from the animal manure (in BI system, animal dung also used) and other organic material and huge amount of nitrogen and phosphorus loses has been seen during the handling and storage of animal manure which usually mount to 30-70% of nitrogen and 4-30% of phosphorus(Zsőfia, 2005). Therefore, the monetary benefit for BI toilet is assumed to be the half of the USD T.

**Nitrogen**

Label on the fertilizer bag indicates nitrogen as pure nitrogen by weight; therefore, the weight for Nitrogen usually represents the percentage weight given of that total weight (Oxford & Oxford, 2010). For example, if urea is labelled with (46-0-0) then, it signifies that 46% of the total weight represents the nitrogen nutrients.

**Phosphorus**

Molecular weight of $P_2O_5$ = 142 grams/mole
Molecular weight of $P$ = 31 grams/mole
Percentage weight of $P$ in $P_2O_5$ = $(31*2)/142$
= 43%

**Potassium**

Molecular weight of $K_2O$ = 94 grams/mole
Molecular weight of $K$ = 39 grams/mole
Percentage weight of $K$ in $K_2O$ = $(39*2)/94$
= 83%

In DAP (18-20-0)

Weight of Phosphorus (P) = 43% * 20% * Weight of Bag
= 0.086 * Weight of Bag

Weight of Nitrogen (N) = 18% * Weight of Bag
= 0.18 * Weight of Bag


In Muriate of Potash ($K_2O$)

Muriate of Potash ($K_2O$) is generally available potash fertilizer. Muriate of Potash (MOP) which is also called potassium chloride (KCL) that contains 60% of $K_2O$.

Weight of potassium (K) = 60% * Weight of Bag
= 0.60 * Weight of Bag

Source: (Balanced Fertilization, nd)
<table>
<thead>
<tr>
<th>Human waste</th>
<th>Nutrient excreted (Kg) per person per year</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
</tr>
<tr>
<td>Urine</td>
<td>2</td>
</tr>
<tr>
<td>Faeces</td>
<td>0.3</td>
</tr>
</tbody>
</table>

*Table. 5. Showing the Nutrient availability in human waste*

Source: (Richert, Gensch, Stenström, Thor, Jönsson & Dagerskog, 2010)

<table>
<thead>
<tr>
<th>Fertilizer</th>
<th>From Market (Kg)</th>
<th>Percentage weight</th>
<th>Weight of Nutrients from Market</th>
<th>Expenditure in fertilizer</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>N</td>
<td>P</td>
<td>K</td>
</tr>
<tr>
<td>Urea</td>
<td>725</td>
<td>0.46</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>DAP</td>
<td>517</td>
<td>0.18</td>
<td>0.08</td>
<td>0</td>
</tr>
<tr>
<td>MOP</td>
<td>100</td>
<td>0</td>
<td>0</td>
<td>0.6</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>426.56</td>
<td>44.46</td>
<td>60</td>
</tr>
</tbody>
</table>

*Table. 6. Chemical fertilizer imported from market and percentage weight of nutrient available in the fertilizer and the total amount of nutrients in Kg imported from market*

Source: (Balanced Fertilization, n.d.)

<table>
<thead>
<tr>
<th>Number of people</th>
<th>USFT</th>
<th>USDT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>P</td>
</tr>
<tr>
<td>156</td>
<td>312</td>
<td>53.04</td>
</tr>
<tr>
<td></td>
<td>312</td>
<td>53.04</td>
</tr>
<tr>
<td>Total (Kg)</td>
<td>312</td>
<td>53.04</td>
</tr>
<tr>
<td>Money Benefit</td>
<td>14921.73913</td>
<td>30837.2093</td>
</tr>
<tr>
<td>Total Money Benefit (Rs)</td>
<td>53948.94843</td>
<td>79319.651</td>
</tr>
</tbody>
</table>

*Table. 7. Illustrates monetary benefit of nutrients from USFT and USDT*

Sanitation alternative will have higher utility for higher money benefit; therefore the utility function was drawn monotonically increasing in order.
3.1.1.3.2. Investment and Cost

USFT and USDT toilet incorporates water conservation and environmental soundness giving economic benefit. In addition, the costliness is actually felt in the beginning of investment but the benefit is long lasting in both urine separating toilets. However, the average cost of Eco-san in Nepal is 16, 000 Rupees\(^5\) (Wateraid, pp. 11-12, 2013). Such dry toilets consist of all concrete structure with concrete pan. The investment cost could vary based on the types of different model of dry toilets. In contrary, new model of urine separating toilets can be a cheapest model among other sanitation alternatives if they are built with hard plastic in commode form which is easily available in Europe which is shown in the Photo 5, 6, 7, and 8. Similarly, the construction of biogas integrated toilet system of 6 m\(^3\) size costs Rs. 31, 515 (Wateraid, pp. 14, 2013). Which is expensive compared to other system therefore government and other organization subsidizes the cost to the people.

Most commonly used sanitation system in the study area is double pit pour-flush latrine system and then one pit pour-flush latrine comes as the second most practiced. Some of the respondent’s household also use direct pit latrine. However, while preferring the mostly used system, Double pit pour-flush latrine costs almost same as the dry toilets system costs and it is Rs. 15,775 (Wateraid, pp. 53, 2013). This is slightly less than the dry toilet.

While considering the cost of USFT, all the collection system and flushing system is similar to the conventional one and to measure the cost for USFT, cost for urine collecting devices should be added to the cost of conventional system. However, in the study area, few household use urine collecting pan to collect the urine but few use direct collection method with the use of a conical flask and collecting jar which is not gender friendly. Hence, the additional cost should not be more than 5\% of initial cost for Double Pit Pour Flush Latrine (PFL).

<table>
<thead>
<tr>
<th>Alternatives</th>
<th>USFT</th>
<th>USDT</th>
<th>BI</th>
<th>Conventional</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost (Rs)</td>
<td>16,564</td>
<td>16,000</td>
<td>31,515</td>
<td>15,775</td>
</tr>
</tbody>
</table>

*Table. 8. Average investment cost for the sanitation alternative based on the material cost in 2007.*

3.1.1.3.3. Operational and Maintenance Cost

According to the Water Aid Report, Urine separating dry toilet need ash, dried biomass as additives which requires some effort and cost therefore, the operational cost for dry toilet found to be 570 Rs per year and similarly, for the pour flush latrine is Rs. 127 per year (Wateraid, pp. 54, 2013). These costs only represent the operational cost.

Small-scale biogas plan of size 6-m\(^3\) requires the waste material from 4 cows. To measure the operation and maintenance cost, a pilot project implemented in Georgia was taken as source that gives operation and maintenance cost for biogas plant. Such biogas plants implemented in Georgia have 1\% of capital costs where the capital cost was USD 120 per cubic m\(^3\) (OECD, n.d.). Which shows that USD 7.2 is the O&M cost for the biogas plan of 6 m\(^3\) size. Hence, the O&M cost for biogas integrated toilet system is Rs 504 while converting the USD amount to Nepali currency for the exchange rate in 2005.

The operation cost for eco-san is 200 per capita per year. While measuring the operation and management (O&M) cost for conventional toilet system, average value of O&M was taken from all the different conventional type toilets system (Wateraid, 2013).

---

\(^5\) Nepali currency is called as Rupees. In short, it is written as Rs.
<table>
<thead>
<tr>
<th>Cost</th>
<th>USFT</th>
<th>USDT</th>
<th>BI</th>
<th>Conventional</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operational (Rs)</td>
<td>200</td>
<td>200</td>
<td>504</td>
<td>400</td>
</tr>
<tr>
<td>Maintenance (Rs)</td>
<td>185</td>
<td>185</td>
<td></td>
<td>175</td>
</tr>
<tr>
<td>Total (Rs)</td>
<td>385</td>
<td>385</td>
<td>504</td>
<td>575</td>
</tr>
</tbody>
</table>

*Table: 9. O&M cost for sanitation alternatives.*

Operational and Maintenance Cost

Utility for O&M cost is similar to investment cost. More the O&M cost, less utility that toilet system will have. Therefore, utility function was drawn in monotonically decreasing in order.

3.2. Study area

Rural Water Supply and Sanitation Project in Western Nepal (RWSSP-WN)\(^6\) has provided working space to carry out all questionnaire preparation, field survey, office space. My work during the field study will be assisted by Water Supply and Sanitation Specialist Mr. Guneshwor Mahato as supervisor for 3 months. The contract work is from 8th of July to 8th of October at RWSSP-WN.

The thesis work is carried out by selecting a study field from the working district \(^7\)of RWSSP-WN named Mahendrakot Village District Committee (VDC)\(^8\) from Kapilbastu District. Kapilbastu district is shown in Figure 4 below. It is additive to the work, that local people from study are known to all the sanitation technologies, which is supported by the fact that RWSSP-WN has already provided urine collecting appliance to some households with proper seminar work and training (Mahato, 2012).

---

\(^6\) RWSSP-WN is a bilateral development cooperation project funded by the governments of Nepal and Finland. This project works at 9 districts to deliver services in water supply, sanitation and hygiene. For more information [here](http://www.rwsspwn.org.np/).

\(^7\) There are 75 districts in Nepal, and the above map is shown with the district boarder line.

\(^8\) Each district has several village district Committee depends on the area, population density, landscape etc.
Kapilbastu District itself has 77 VDC’s which can be seen in Figure 5 below. Mahendrakot VDC is one among the 77 VDCs located in the North West part of Kapilvastu district. The population of this VDC is 8418 of which 4255 are male and 4163 are female from a total of 1488 households. (Water, Sanitation and Hygiene Plan, 2010/2011)
General features of Kapilbastu District

- Latitude: N27°40'52.2" - N27°45'37.9"
- Longitude: E83°02'50.8" - E83°02'58.1"
- Altitude: 121 m – 192 m
- Climate: Warm and humid
- Temperature: Max. 42° C and Min. 6.4°
- Rainfall: 1285 ml/year
- Land: Plain and fertile
- Rivers/pond: Kondre, Gudurung Rivers and Pond of Bhelai
- Occupation: Agriculture
- Agricultural Products: Rice, Wheat and Vegetables

Source: (Water, Sanitation and Hygiene Plan, pp. 1, 2010/2011)

Mahendrakot VDC consists of 9 small wards, numbered 1 to 9. Specifically, the study field are Birpur-6 and Changath-9 number wards. The study wards are shown in Figure 6 below. The Mahendrakot VDC has already declared Open Defecation Free (ODF) but still many of the household do not have permanent toilet. Description of the study field is given in the Table 8 below.

<table>
<thead>
<tr>
<th>Ward Number</th>
<th>Name of Ward</th>
<th>Population</th>
<th>Household</th>
<th>Permanent Toilet</th>
<th>Temporary Toilet</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>Birpur</td>
<td>1845</td>
<td>320</td>
<td>182</td>
<td>138</td>
</tr>
<tr>
<td>9</td>
<td>Changath</td>
<td>623</td>
<td>118</td>
<td>51</td>
<td>67</td>
</tr>
</tbody>
</table>

*Table 10. Description of surveyed ward Birpur-6 and Changath-9, Source: (Water, Sanitation and Hygiene Plan, 2010/2011)*

9 All over the Nepal, Every VDC has 9 wards in it.
3.3. Household questionnaire survey

Questionnaires were developed to facilitate the Decision Support System (DSS) tool Generic Multiple Attribute Analysis (GMAA). Questions were in the form of Yes/No type, ranking people’s responses in the form of 1 to 5 as intensity, and general knowledge questions concerning the different sanitation alternatives and diverse socio-economic attribute. See the Annex 1 for detail. Household survey was carried out with a member of every household which almost took one hour for each house.

Thirty number of household were surveyed from the area where few people were found to be using urine separating appliance in their sanitation practice along with growing vegetable with the use of urine. Surveyed locations are Birpur and Changath with ward number 6 and 9 respectively. Respondents were divided into two groups, one from the household survey and other group comprises of officials who were associated to sanitation related work. For example, Village WASH Coordination Committee (VWASHCC); VWASHCC is a VDC level coordinating body mainly accountable to the VDC council and headed by VDC chairperson/members and Community Hygiene and Sanitation Action Committee (CHASC); CHSAC is the community level executing committee elected/nominated by the community comprising 9 to 13 members including at least 50% women and proportionate representation from excluded group (Water, Sanitation and Hygiene Plan, pp. 14, 2010/2011).

Few photos from the questionnaire survey are shown below. Likewise, interaction with the urine user was also carried out to get the information on how user has taken USFT as a sanitation toilet system.
3.4. Interaction with locals volunteers on eco-sanitation

A seminar program was carried out at VDC office with the local volunteers who are involved in water supply and sanitation which is shown in photo 2 below. During the interaction, a model of urine separating dry toilet was demonstrated and explanation on the benefit of it in using were shared. Information regarding the other sanitation alternatives, use of chemical fertilizers, and social data were collected during the seminar.
3.5. Sanitation Alternatives

3.5.1. Urine Separating Flush Toilet

USFT is also called as wet eco-toilet; it is the combination of a dry toilet and an ordinary flush toilet (Roxendal, 2012). This system deals with the urine and its collection without letting it to be mixed with faeces. Faeces are collected in direct pit latrine system or in septic tank by flushing it with water. But while collecting urine, system needs a safe passage way for urine to reach collection tank or via polythene pipe to the Jar or directly collecting in jar without using any piece of equipment. Pit hole are either constructed with the concrete ring or without any barrier to soil, however; basement of the pit hole is always left open even the concrete ring are used on the wall of pit hole.

Collected urine will be pathogen free after 6 months of passive storage. Then it can be used in the field. There is a technology to convert this liquid urine to the powdered form of fertilizer called struvite that contains all of the phosphorus and most of the nitrogen, magnesium and calcium (Bamhart & Maingay, 2011). However, USFT user in the field is not aware of such methods on urine application. Therefore, users mix urine to water and then use it in the field.

Few households in the study area found to be practicing urine separating flush toilet (USFT) by only means of direct collection of urine in jar. Faeces are flushed out to the pit hole with water as shown in photo 3 on left; however toilet pan facilitated with urine separating equipments are not used. Similarly, one user was practicing
a better collection system for urine and faeces into two different pit hole with properly designed pan system where two passages for urine and faeces were used as shown in photo 3 on right. Based on local technology, such toilet can be divided into two categories, urine separating flush toilet with collection pipe and without collection pipe.

This system shown below in left photo is easy to promote in rural areas where advanced toilet pan are not easily available. Advanced toilet pan for USFT generally have both urine and faeces separating facilities. The left picture below is an example of temporary type of USFT, which can be improved to appropriate USFT pan that easily separates urine and faeces. As discussed above, the USFT with inappropriate way of urine collection, such toilet systems take a lot of time compared to the other flush toilet and not a gender friendly toilet system as well.

Such direct urine collection system with the use of cone and jar was initiated by RWSSP-WN. They provided necessary accessories to few households to collect the urine with information on how to collect and use it in vegetables field. Likewise, urine separating pan was also installed to a house to make the surrounding communities aware of such sanitation system and urine use in field.

3.5.2. Urine Separating Dry Toilet (USDT)
Urine Separating Dry Toilet (USDT) system is also called as ecological sanitation because all the nutrients in human waste go back to the field being new fertilizer resources for plant. Such toilet system reduces the environmental degradation. Werner defines it as the material-flow cycle instead of disposal (Werner, 2013). Faeces and urine are sanitized by composting or dehydrating. Urine are collected in a closed vessel for 6 months to make it free from pathogens respectively (Esrey, Andersson, & Sawyer, 2012). Basically, the aim is to process urine and faeces in a different way to extract the nutrient, where excreta are processed until it gets free from pathogens and inoffensive. There are various types of urine separating dry toilets appliances available in the market however; they are not easily accessible to the rural people. In contrary, Nepalese are accustomed with use of water for anal cleansing. Therefore, three different passage ways for faeces, urine and anal cleansed waste water need to be incorporated in the toilet system and surprisingly; dry toilet pan has already been constructed with three passages for urine, faeces and anal cleansing water and available in market in Nepal.
USDT is considered as ecologically sound sanitation system. Nutrients recovery and no environmental degradation from USDT are the primary benefits of practicing USDT is also supposed to be ecological approach in upgrading the social, economical and environmental aspects of society by providing the local fertilizer, by not polluting water and air, by upgrading the economic status and mostly by impeding the use of chemical fertilizer (Wateraid, 2013). However, it is time consuming sanitation practice and requires well management from the user. And even the cost is expensive than other sanitation system. In addition, user has to change their location while cleansing anal. In contrary, dry toilets in commode form can be a solution as user friendly, gender friendly and moreover, if one more passage for anal cleansing water is developed within it, commode form toilet might function very well.

3.5.3. Biogas Integrated Toilet (BI)

Biogas integrated toilets where toilet wastes are mixed with the manure, cow dung, and water. the mixed pile of human waste and cow dung then put in the composter tank, eventually producing methane gas which is taken as source of energy for cooking and lightening in the rural areas. Since, human waste are recycled to biogas and fertilizer as end product in biogas integrated toilet system, it is considered as a excellent system in sanitation and renewable energy sector (Wateraid, 2013). However, land requirement expensive structure need, and livestock are the primary resources a biogas plant needs. One example of biogas integrated sanitation system is shown in photo below.
Such sanitation system reduces the indoor air pollution and improves the health and hygiene of the family. Similarly, it saves time in fetching the firewood from forest and eventually preserves the nature. The end product from the biogas plant can be used as the organic fertilizer which contains all the nutrients needed for the plants. By recovering the renewable energy and the fertilizer as the end product has made this sanitation system promising one (Forte, 2011). However, a household with livestock and economically stable family can only build such sanitation system and the need of large amount of water during the mixing of wastes with dung, manure which could be inappropriate for a water scarce area.

3.5.4. Conventional Toilet (CT)
There are some toilet system where human waste are collected in pit hole and after when it gets full, it is covered with soil and toilet is moved to a new place with new pit hole, such toilet system is called Conventional toilet (CT) system. Pit latrine, ventilated improved pit and toilet with septic tank are the most common toilet system where human wastes are left unused. Therefore, all toilet systems that are common in rural areas, and where human wastes are not used as fertilizer, are named as conventional toilet system.

Direct pit latrine is temporary type of toilet in which a pit is dug and covered with concrete slab or wooden plank with a temporary type of toilet pan. Human wastes are stored in the pit until it gets filled. Basic materials used in direct pit latrines are lining materials as bricks, stone, concrete or some time bamboo mat are also used. Filled pit are emptied or buried and another pit is dug for waste collection. Chances of ground water contamination from pits, unhygienic in practice, odour problems attracting flies and mosquitoes are general problem associated with pit latrines. (ENPHO, pp. 7, 2006)

Ventilated improved pit latrine (VIP) is improved conventional toilet than the direct pit latrine because it has a ventilation pipe used in it to pass the offensive gases out to air. Similarly, a concrete slab including a toilet pan in it is also used. Generally, people use brick wall and cheap concrete slab over it to build VIP toilet. However, in offset pit latrine, a more developed passage way generally made up of polythene pipe to pass the human waste to the concrete pit or natural pit. Which means the toilet could also be inside the home. Double pit system is also used in offset pit latrine system. Finally, when the pit are replaced with the septic tank, such system are called toilet with septic tank. Water is used to flush the faecal material, and once the tank gets filled up, it is removed and dump into the open area. (Pradhan, pp. 12-13, 2008)
4. **Results and findings**

4.1. **Survey findings**

Questionnaire survey gave clear data on which sanitation systems are practiced more in the rural areas which is shown table 8 below. The numbers of the respondent were thirty households. The available sanitation alternative as discussed above were found to be conventional toilet as flush toilet, pour-flush toilet, septic tank, and double ring pit hole that are mostly practiced toilet system though septic tank toilet system found to be practiced by very less number. Similarly, USDT and USFT were found to be known to 89% of users which is shown in figure 6 below.

**Figure. 7.** Showing percentage of Respondents known to Eco-san. **Table. 11.** Types of toilets in use in study area

Most of the respondents were farmers and they have been using fertiliser in the farm. Locally available fertilizer as manure, cow-dung, pig excreta, and human waste etc are easily available fertilizer for them. Instead, they also use chemical fertilizer Urea, DAP, and Potash from market because local fertilizers are not enough for the agricultural need. Macronutrients (Nitrogen, Phosphorus, and Potassium) are the most essential elements that a plant needs in a large quantity in order to grow (FAO & IFA, Fertilizer and their use, 2000). Measurement was carried out to find the weight of macronutrients Nitrogen, Phosphorus and potassium in Kg bought from market in a year and amount of those nutrients that is possible to recover from the human waste. Corresponding results for the sanitation alternative that is associated with the use of human waste as fertilizer is shown below.

**Figure. 8.** Showing Nitrogen and Phosphorus demand and Possible Extraction from USFT and USDT system.

Above figure 7 illustrates the amount of nitrogen, phosphorus and potassium that is possible to extract from USFT and USDT systems. Users generally buy chemical fertilizers as UREA, DAP and Potash to fulfil the nutrients need of plant. Solution could be to link sanitation system to the agriculture and users can avoid the use
of chemical fertilizers which is expensive. From the above figure, the nitrogen demand in total for all the surveyed household is 426.56 kg and users has to buy them from the market. However, USFT and USDT can fulfil nutrients demand in certain level. Above figure shows that 421.2 kg of Nitrogen can be extracted from the use of USDT toilet and 358.8 kg from USFT. Similarly, the demand for phosphorus in the study area is 102.26 kg, and users are buying MOP from market to fulfil the plant’s need. However, USFT and USDT can provide 46.8 kg and 62.4 kg of phosphorus respectively if only human wastes are handled properly. In case of potassium, more than 90% of respondents do not use Potash in their field and it is unclear, why users are not using potash as compared to urea and DAP. It might be the case that the locally made fertilizers have fulfilled potassium need.

4.2. GMAA results

4.2.1. Alternatives ranking with utilities

Overall ranking of the alternatives gives the optimal alternative which is shown in figure 8 below.

Figure 8 confirms that biogas integrated toilet system is the optimal sanitation alternative for the study area with utilities value 0.4816 which is followed by USDT system with utilities 0.4427. The yellow marks show the overall utilities value for the alternatives where interestingly, conventional toilets system and USFT system have almost the same utilities value. Therefore, it is not realistic to say which one is the least preferable alternative. In addition, conventional toilet system and USFT system are likely to fall in a same category because most of the methods are same in both toilet systems except the collections of urine in USFT. Similarly, both BI toilet system and USDT system are ecological compared to USFT and conventional toilet system because, in BI and USDT toilet systems, human wastes are completely converted to fertilizer and used in the field. It is interesting to know from the above figure that users prefer BI and USDT system.

However, above figure represents the overall result of the GMAA analysis that provides information on which alternative is preferable and optimal one for the study area. Further comparison and analysis between the alternatives will show the challenging issues attached to specific alternative compared to other alternatives.

4.3. Optimal solution for different objective aspect

The GMAA study was carried out based on four different objectives aspects that are associated with sanitation system. The study has already shown the optimal alternative for the study area based on various objective aspects however; the optimal alternative would vary based on different object aspect.

4.3.1. Technical aspect

From the figure 10 below, conventional toilet system came as the optimal sanitation alternative based on technical aspects, while BI toilet system as the second optimal alternative. They both have nearly equal utilities. Similarly, USFT and USDT have low utilities value that is why both the systems are least optimal toilet system. USDT is the least preferable alternative technically.
4.3.2. Social aspect

Figure 11 below shows that, conventional toilet is the optimal alternative among all followed by BI as a second optimal sanitation alternative. USFT and USDT are the least preferred alternative socially. Hence, it can be referred that ecological sanitation are not accepted socially in the study area.

4.3.3. Environmental aspect

Figure 12 below point out that USDT as the optimal alternative based on environmental aspects which is then followed by BI toilet system. Environmentally, dry toilet is more environmental friendly and then biogas integrated toilet.

4.3.4. Economical aspect

Based on economic aspects, Figure 13 below shows that USDT is the optimal alternative and USFT is the second optimal alternative. Investment cost, O&M cost, and monetary benefit from those alternatives were measured and ranked in this figure 18 below. Conventional toilet is economically not feasible compared to others as shown in figure 18 below. However, the investment cost for BI is quite expensive than conventional toilet but the monetary benefit from BI has made it one step better than the conventional toilet.
The ranking of the sanitation alternatives based on different objective aspects can be formed in the table 9 below. The table gives clear and summarized ranking of alternatives.

![Graph showing ranking of alternatives based on economical aspect.](image)

**Figure. 13.** Showing alternatives ranking based on Economical aspect.

<table>
<thead>
<tr>
<th>Socially (Ranking of alternatives)</th>
<th>Technically (Ranking of alternatives)</th>
<th>Environmentally (Ranking of alternatives)</th>
<th>Economically (Ranking of alternatives)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2. BI Toilet</td>
<td>2. BI Toilet</td>
<td>2. BI Toilet</td>
<td>2. USFT</td>
</tr>
<tr>
<td>3. USFT</td>
<td>3. USFT</td>
<td>3. USFT</td>
<td>3. BI Toilet</td>
</tr>
</tbody>
</table>

**Table. 11.** Showing alternative ranking based on objective aspects
5. Interpretation of the result

5.1. BI and conventional toilet systems

The optimal sanitation alternative for the study area is BI system however; conventional toilets are more common in the user level. Table 8 shows that, number of BI system reported is 5 and numbers of conventional toilet system are in 23 numbers. Therefore, comparison between BI and conventional toilet system is done below to see the differences between them in attributes level.

Environmental and economical attributes were calculated based on facts and figure; there is no user’s perceptions used in measuring optimal alternative on these objective aspects. However, social and technological attributes were measured based on user’s belief and on their responses towards these attributes. Therefore, optimal alternative could vary based on user’s preference over social and technological aspects if study is carried out in other different location. When result is considered separately for environment and economic aspects, USDT is optimal alternative for all rural areas of Nepal. However, based on figurative calculation, BI is optimal alternative for the study area.

In figure 14, the bar for each attribute is the subtracted utility value from one alternative’s attributes utility value to another among whom the comparison is carried out. Attribute with blank part does not mean that the alternative do not have any utility value for that attribute. In contrary, it suggests that they have equal attribute values and got cancelled while subtracting one by another. However, the total difference of utility is facing towards the BI toilet system, which means, BI is optimal sanitation system compared to CT.

Below figures illustrate that conventional toilets are technically favoured than BI toilet by the users. User preferences toward CT are based on the recycling method that CT system has; easiness in use and in contrast CT system has been promoted naturally in the community. Space requirement in BI toilet is challenging for users whereas, in CT system, small space works well. BI system also requires the human effort to mix the human waste with livestock dung and water. In rural areas, women are mostly responsible for such work. Therefore, CT seems favourable for women and this is why CT is preferred than BI in terms of women role. Handling of human waste creates negative impression over the toilet system and that might have led users to believe that BI is susceptible to infection. When users are asked to choose hygiene one among CT and BI, users showed equal hygiene utility to both BI and CT system.

![Figure 14. Showing subtracted attribute value for technological aspects of BI and Conventional toilet system.](image)

From figure 15, in cultural taboos, there is not much different view user have on BI and CT system, however, users showed little more behavioural utility towards BI than CT. This signifies that more users have shown positive behaviour towards the BI.
From Figure 16, BI toilet system is optimal environmentally and economically. However, there are few economical issues that favour CT rather than BI toilet system. For example, investment for CT is low compared to investment on BI. Since the rural people cannot afford such a massive investment, users easily go for CT that costs half of BI cost. Currently, conventional toilets are more practiced because it is economically cheaper and easy to construct. If users are aware of the fertiliser value of human waste therefore, users are handling and using the waste in field as fertilizer in BI toilet system. Users have put more utility value toward fertiliser execution in CT toilet system. Most importantly, when a user is asked to build a toilet by government officials or any non-governmental organization, CT is the primary choice because the GMAA result has shown that, CT is optimal among the user socially and technologically.

The environmental problem are created comparatively high in CT system, therefore BI toilet system has more utility values in terms of air and water pollution which can be seen in figure 16 below.

**Figure. 16.** Showing subtracted attribute value for economic and environmental aspects of BI and Conventional toilet system.

### 5.2. Comparison between USDT and CT based on technological aspects

Similar illustration of differences between CT system and USDT can be derived from the chart bar graph shown in figure 17 below. Below bar illustrates that users prefers CT toilet systems than USDT in social and technological aspects considering the issues recycling methods of human waste, equipment accessibility, gender friendly technology, women role and stakeholders associated to specific toilet. In CT toilet system, there is no need to recycle human waste whereas in USDT, users have to put effort in separating, storing, and storing it for several months. Storing human waste in CT toilet system requires one pit hole and it is usable until it gets filled up but in USDT, collected urine and faeces has to be stored in different place or below the toilet in bucket like structure which eventually needs handling and proper management.
USDT is optimal toilet system in terms of environmental and economical aspect. Users could have economic benefit from the use of USDT, however, CT system is practiced in large number and economic and environmental benefits are out of reach. Investment is however same for USDT and CT systems unless users do build a simple direct pit latrine without brick wall. Since, Monetary benefit is possible only from USDT, operational and maintenance cost was found to be low for USDT than CT system. The cost in emptying the filled pit hole in CT system is costlier compared to the operation and maintenance cost needed in USDT. In USDT, operational and maintenance costs signifies handling and managing human waste and used as fertilizer. There are no ground and surface water pollution from USDT system. In addition, air is also not polluted by USDT which can be seen in figure 17 below.

*Figure. 17. Comparison of technical attributes between Conventional toilet and USDT.*

Similarly, cultural taboos as we already know it as a complex human behaviour that is the result of his/her life experiences and the environment where he/she lives. Here, attitude, motivation and behaviours are discussed as the cultural taboos that are rooted to religion, culture, societal environment (the thesis already have discussed the attitude, behaviour, and motivation in above attribute discussion). User’s attitude and motivation favours CT system however, but users support the idea of converting human waste to fertilizers as a behaviour but attitude and motivation that stops users to practice USDT. In short, the study shows that their attitude motivated them to prefer CT toilet system however, user show positive behaviour towards handling and management of urine and faeces. Therefore, in figure 18 below, users shows little more behavioural utility towards USDT.

*Figure. 18. Comparison of social attributes between Conventional toilet and USDT.*
6. Discussion

6.1. Survey result
Sanitation alternatives that exist in study areas are basically CT, BI, USFT and USDT. USFT and USDT are new toilet system for the users. However, the survey finding has showed that 90% of users are aware of USFT and USDT systems which are shown in table 8 and that fact helped in choosing USFT and USDT as sanitation alternatives. Most of the users are well known to all the available toilet systems. Therefore, the thesis can choose these four toilet system as sanitation alternatives for all the users in the study area.

6.2. GMAA result
Figure 8 show that BI system is optimal sanitation system for the study area. Here, the optimal alternatives means, based on all social, technological, environmental and economical aspects, BI is best toilet system for the study area. However, Table 8 shows that majority of the users are practicing CT systems despite the availability of other sanitation systems. It is unclear that why all sanitation systems are not equally practiced. In addition, the BI being an optimal alternative is also not practiced by more than fifteen percent of the users. The reason could be understood by knowing what motivates users to practice CT system.

First, table 9 clearly shows that, users prefer CT system for its technological easiness and socially accepted nature. However, it cannot be said that users practice it only because of social and technological aspects of toilet system while choosing toilet system. User’s idea about all sanitation alternatives was surveyed and used only for social and technological aspects of toilet systems in GMAA study. In similar way, facts and figure based calculation were made for environment and economical aspects. Therefore, CT systems are more common to users because of its social and technological appropriateness. It is clear from the result that users have not considered the economical and environmental aspects while choosing a sanitation alternative.

Secondly, Direct pit latrine systems are being promoted at first as temporary toilet system as to increase toilet coverage however, no socio-economic evaluation is carried out before any toilet is promoted in a region. Since, the goal is always to increase the toilet coverage which starts with declaring open defecation free zone, working non-governmental organizations and other governmental organizations do not primarily focus on the evaluation of toilet system. Governmental and non-governmental agencies who are working in the field of sanitation to increase toilet coverage in the rural areas merely focus on appropriate type and design of toilet system. As a result, conventional toilets as pour flush toilets, pit latrines are increasingly practiced without any proper design and construction (ENPHO, 2006). User basically goes for CT system because stakeholders do not discuss about the availability of other toilet system which led user to follow CT system.

6.3. Sustainable sanitation system
Growing environmental concern can no longer accept any toilet system that does not fulfill the long term sustainability. Therefore, it is very important to escalate the use of an appropriate toilet system that is environmentally sound, sustainable. As discussed above during introduction, it is possible to link toilet system to agriculture, urbanization, environment and health. Langergraber and Muellegger (2004) conclude their study saying that the objective of sanitation systems should be to minimise hygienic risks and protect the environment by returning nutrients to the soil and conserving valuable water resources. Nutrients recovery and its use in field help soil to become fertile as it was before. Such method balance the nutrients quantity in soil so it works in an ecological cycle and at the same time can fulfill the need of chemical fertilizer.

BI toilet system
Overall ranking of the toilet system gave BI toilet system as optimal system for the study area. In general, if this GMAA study is carried out in any rural areas on Nepal, BI would come as optimal choice. BI toilet system is considered as the environmental friendly and appropriate technology for developing countries where having livestock at home is common and deforestation is major issues. It provides cooking fuel, lighting facilities, improve social condition by providing healthier environment in kitchen and saving women’s time in fetching fuel wood from forest (Bajgain & Shakya, 2005). Local people from study area also heavily depend on forest for fuel wood and deforestation has also been a major issues. Therefore, BI system is also taken as an alternative to resolve the deforestation issues however; BI toilet system requires livestock at home and a massive investment that is not possible for every households to have. Therefore, BI toilet system cannot include all the users and still most of the users have to depend on fuel wood. There is possibility that the proper management of forest can serve the users need for fuel wood for long run.
Since, all users do not have livestock at their home and financially cannot afford massive investment for BI system; donor agencies provide subsidy to install BI toilet system. From field survey, it was also found that, all users who constructed BI toilet system was subsidized by donor agencies. Similarly, in BI toilet system, 30-70% of nitrogen and 4-30% of phosphorus are lost during handling of waste (Zsöfia, 2005). Therefore, in BI toilet system, all nutrients do not return to field. In addition, BI system also requires comparatively more space than any other system requires. Space taking toilet system will not be appropriate system in future in the time of growing urbanization in rural areas. Therefore, BI does not look sustainable for long run. However, it is socially and technologically more accepted by users than USFT and USDT systems.

CT system

CT systems is socially and technologically accepted toilet system in study area (For more description about social and technological, please see interpretation of results). And it can be generalized that CT are mostly practiced toilet system in rural areas of Nepal because of its socially accepted and technologically easy while using. However, Table 9 show that CT toilet system is does not consider environment and economic benefit that is possible to achieve from human waste.

CT systems are built on the basic assumption that faecal materials are waste and it should be disposed. Consequently it contaminates air and ground water with pathogens, bad odour, fly/mosquito breeding etc. It basically affects agricultural sector by reducing the nutrients amount in soil that is supposed to go back to soil as fertilizer. It is not possible to create sustainable society with the use of CT system in the time of growing urbanization and need of sustainable sewerage system in future (Langergraber & Muellegger, 2004). Air and water pollution is highly polluted by CT systems. However, few farmers found to be using the human waste as fertilizer with CT system. Collected human waste in pit turns to fertilizer after a several months but there are ground water and air contamination from the waste.

Therefore, long term sustainability from CT system cannot be expected. Stakeholders working in increasing toilet coverage divide the implementation process as installing temporary toilet (direct pit latrine) at first and then permanent (VIP toilets) to stop open defecation, a better change in the implementation can be brought by naming CT systems as temporary toilets system until the sustainable one is installed.

USDT and USFT systems

GMAA study has shown in table 9 that USDT and USFT are environmentally and economically appropriate toilet system. However, these toilet systems are not accepted socially. Technological aspects of these newly practiced toilet systems are time consuming in practice compared to the CT system. USDT and USFT system requires human effort to collect and manage human waste. This is why; users prefer CT and BI technologically. Besides, nutrients are recovered in USDT and USFT without any loss during handling which is economically viable in the rural areas where users highly depends on the chemical fertilizers in agriculture. Nutrients recovery is higher in USDT than USFT and if it is used, nutrients can flow directly from field to human and human to field in an ecological manner. Use of such nutrients recovering toilet system will make farmer less dependent over the chemical fertilizer.

In addition, use of faeces and urine in farming results organic yield. Human wastes are more organic compare to chemical fertilizer that helps soil to make more airy and loose. Similarly, soil mixed with faeces and urine holds moisture and nutrients for long run building a favourable environment for earthworms. (Organic vs. Synthetic Fertilizers, 2006). Hence, it is crucial here to state that if sanitation system is linked to the extraction of nutrients, it would make agriculture system organic and independent to chemical fertilizer. In contrast, USFT system pollute air and water more than USDT because faecal matter is flushed and collected as in CT system which is explained in table 3 and 4. Therefore, USFT is not environmental friendly toilet system.

Centralized sewerage systems are built to serve the densely populated areas. Since, rural areas in Nepal are also going through urbanization and such centralized sewerage systems will be needed in future. But the massive investment for centralized sewerage system is not affordable for developing countries like Nepal and continuous loss of nutrients will demand chemical fertilizer. Individual septic tank toilet system is also common in urbanized cities in Nepal that belongs to CT system category which is already discussed as unsustainable toilet system in above paragraph. Therefore, viewing the future demand for appropriate sanitation, USDT would be the best toilet system that is sustainable in long run as well. In health aspects as well, if properly managed it can be improved as hygiene sanitation alternative (Märtensson, Torstensson & Winblad, 1998). When faeces are not mixed with water and urine, there are less chances of bacterial activity in dry faeces. Proper handling and management of human waste can make USDT as most healthy and hygienic toilet system. Study has showed
that use of dry toilets can save up to 40% of indoor water use (Cordova, 2001). Since study area is facing water scarce situation, USDT could halve the scarce water demand.

In a similar way, government master plan expect the toilet system to possess improvement in public health, economic growth, social inclusion, protection and optimising investments, environmental protection, and an efficient, effective and accountable urban water supply and sanitation sector (Sanitation and Hygiene Master Plan, 2011). However, predominantly used conventional toilet does not fulfil the above terminologies and already categorized as unsustainable. USDT has the potential to fulfil above terminologies. We have already discussed the issues; public health, monetary benefit, environmental protection and an effective sanitation plan for urban and found that USDT system can help in achieving these goal. USDT also brings equality in society because the cost for USDT is same for all. Predominantly used CT system has different types with different costs; for example, septic tank toilet is expensive and socially assumed to be most hygienic toilet system which is only affordable to those families who are financially strong. Similar way, direct pit latrines and VIP toilet system are cheap and options for poor families. Expensive septic tank toilet system tends to be installed by rich family. Therefore, CT systems do not include all the families socially.

Hence, USDT is appropriate toilet system for rural areas in Nepal which is economically viable in agricultural aspects, no need of any centralized system in future, environmentally best among all the system and hygienic toilet system if managed and handled properly. USDT also meet terminologies that government formulated in master plan for water supply and sanitation.

6.4. Ecological Sanitation and its Promotion in rural areas

Ecological sanitation

Urine separating dry toilet has come up as the sustainable sanitation system because the system successfully influences all indicator defined by government. Book published by Swedish International Development Cooperation Agency (Jones, Rolf and Ab, 1998) states that a sanitation system where human excreta are safely handled so as to prevent the environmental pollution and the collected urine and faeces are sanitized for agricultural purpose is called ‘ecological sanitation’ or ‘eco-san’. Langergraber & Muellegger (2004) states that ecological sanitation is an alternative ecological approach to close the nutrient flow cycles. Figure below shows the circular flow of nutrients between farming and society which can only be fulfilled by the application of ecological sanitation as a sanitation alternative.

Dehydration and Decomposition are two types of method used in ecological sanitation to make excreta a safe fertilizer. In dehydration method, moisture content of the faeces is removed as soon as possible below 25% by adding dry material or with the help of sun light. If the moisture content is dropped to low level, there will be no smell and problem of fly breeding (Jones, Rolf and Ab, 1998). In decomposition process, there is not any breakdown of organic material. Therefore, used toilet paper is not supposed to be mixed with faeces because it will not disintegrate. However, water is used to clean the anal in Nepal. Therefore, collected anal cleansing water can be mixed to urine or collected separately as urine for further treatment.

Dehydration Method

A typical example of dehydration type ecological sanitation system practiced in Nepal is shown below. The system has two vaults to collect faeces which are bigger in size and small two chambers to collect urine and anal cleansing water. This system does not discharge any waste water outside of it. One chamber is used for collection of faeces until other filled chamber with faeces is dried up and ready to use as fertilizer (Shrestha R.R., Shrestha P., Paudel U., Shrestha P., and Manandhar A., nd). This system is similar to the double vault dehydrating toilet used in Vietnam, Mexico, Sweden and Central America. Double vault system was built to kill
the pathogens by removing moisture content of faeces by adding moisture absorbing material like ashes after each use. Urine tank as shown in figure below or collection jar behind the toilet is used to collect the urine. Urine is also mixed with water, lime or ashes. Then, Urine or the urine with ashes or lime is used as fertilizer. And the faeces are collected in one of the chamber until it is full and then leave the filled tank for dehydration. For the continuous use, second chamber is used when the first one is in dehydration process (Jones, Rolf and Ab, 1998). Most of the conventional toilet discussed in this thesis also goes through the dehydration process. However, the dehydration of faeces, urine and anal cleansing water is in the ground without any precautions to environmental problem. Otherwise, the conventional toilet systems are also a form of ecological sanitation where wastes goes through dehydration process and can be used after a usual retention time of 8-12 months.

![Figure 20. Composting toilet with liquid separation. Source: (Wateraid, n.d.)](image)

**Decomposition Method**

Decomposition method is the biological process which disintegrates organic material added in the faeces into humus. Decomposition of organic material has a certain requirements such as moisture content, carbon and nitrogen ratio and availability of micro-organism. Sufficient amount of oxygen, carbon nitrogen (C/N) ratio between 15:1 to 30:1, and temperature above $15^\circ$ is needed during the decomposition. To maintain the carbon nitrogen ration, additives as sawdust, kitchen refuse, toilet paper, weeds, and grass clippings are added (Jones, Rolf and Ab, 1998). The average temperature in the study area varies from $6.4^\circ$ to $42^\circ$, which suggests that most of the time the temperature is favourable for the decomposition. Organic materials are found in abundance since local inhabitants use forest product in excessive amount. Therefore, it seems more appropriate to encourage people from the study area to go for ecological sanitation with decomposition process. There are few examples of ecological sanitation with decomposition process which are shown below.

![Figure 21. liquid separation composting toilet. Source: (Jones, Rolf and Ab, 1998)](image)

![Figure 22. the `Carousel` composting toilet, Norway. Source: (Jones, Rolf and Ab, 1998)](image)

Figure 1 is an example of composting toilet where a collection bin of suitable size is used to collect the urine and faeces. This is also called as movable bin toilet. The bin has special design in it to drain out the liquid from...
the bottom and finally end with evaporation. Air circulates the bin from the cut out near the base of the bin and also with the help of perforated ventilation pipes running through the bin. Similarly, figure 2 is a typical of composting toilet from Norway which is called ‘Carousel’ or multiple vault composting toilet. It also has the similar process as the movable bin toilet. However, the collection tank has four chambers in it so it does not need to be moved after when it is full. When a chamber gets full, rotating the tank results in opening of new collection chamber. Similarly, decomposition process also starts in the filled chamber with the liquid drain out from base. The size of the cylindrical tank must be designed such a way that the chamber volume is enough for a year so as to give the retention time of 8-12 months for decomposition process (Jones, Rolf and Ab, 1998). Both system can be processed with additives (grass clippings, sawdust, kitchen refuse etc). In Uppsala, Sweden, few local people are practicing such method where urine and faeces are collected separately. Faeces are then mixed with the organic material from garden and then leave it in a box designed to pass sufficient amount of air for decomposition process.

**Promoting USDT system**

As it is clear from the comparison between USDT and CT system that USDT system are not socially accepted and technological features are also weak compared to CT system. Therefore, social and technological aspects of USDT must be focused in order to promote USDT system.

A study carried out in Nepal in 2010 in seven communities where urine and faeces separating toilets were promoted, study showed that the USDT system should be technically comfort. Only then USDT system is socially accepted. Similarly, knowledge on scope and use of urine should also be shared within communities which are psychologically inherent to the people behaviour. Therefore, such aspects are more crucial in promoting dry toilets (Khatri, 2012). Below figure represents how different stakeholders as government, government offices and non-governmental organizations as motivator in rural areas, and local people with their own local government are interlinked in the present scenario of study area.
Figure 23. General view of sanitation related stakeholders from government level to local user level along with the various aspects of toilet system. Bold objectives are crucial to change user’s motives to bring sustainable toilet system.

Figure 19 shows social and technological aspects as the crucial aspect in promoting USDT system in the study area. Sanitation system is an interlinked human behaviour with other stakeholders. For example, government makes rules and plan to achieve sanitation goal at the higher level, which is followed by motivator as governmental organization and non-governmental organization to increase the toilet coverage. There comes a local government or a board with the local politician, volunteer to fill the gap between rural people and governmental organizations. In general, if it is to promote USDT in rural areas of Nepal, these three authoritative groups as government, working organization as motivator, and local government of users have to focus on USDT system and its promotion. Government should formulate policies especially on USDT promotion and substantial public subsidies must also put in research to improve technological aspects of USDT. Pilot projects in the rural areas can also act as a catalyst to boost the knowledge about the USDT system and in which local government will have to assist the organization. Evaluation and monitoring of the pilot projects has to be carried out frequently.

Cultural taboos are a social barrier in promoting USDT system. Cultural taboos can be found in all the authority people working from government level to the local government level, therefore, it is not just the user’s taboos that have to be dealt in promoting USDT system. Use of human waste as fertiliser is a complex and anti-human concept for most of the users and it is not easy to change that taboos. Therefore, good promoting policies to bring change in users will not be fully achieved until the promoters themselves are well aware of USDT system. Similarly, Users usually hire low caste or poor people to empty the filled pit in CT system because it is not acceptable for families to touch or handle their waste by themselves. Therefore, if authoritative people practice such sanitation system at their home as an example, only then user feel more comfortable and safe in practicing USDT consequently leading to the feeling of socially accepted. Government and other funding agencies has to put more fund and interest in USDT system and all stakeholders must be active focusing only on USDT promotion.
7. Conclusion

Conventional toilet and biogas integrated toilet systems are common toilet system in rural areas of Nepal. However, in the study area; RWSSP-WN had started urine separating flush toilet system two years ago, which made users well aware of urine separating flush toilet and urine separating dry toilet as well. Therefore, there are four toilet systems available in the study area. Finding the optimal alternative in terms of social, economical, environmental, technological aspects is necessary to bring the sustainability in sanitation system. Similarly, increasing toilet coverage with a proper sanitation system might have a long term impact on environment, and society.

From the GMAA study, biogas integrated toilet system came as the optimal sanitation system in terms of social, technological, environmental and economical aspects. However, conventional toilets are practiced by the most of the users in the study area. Cultural taboos and working stakeholder’s continuous focus on conventional toilet has made conventional toilet mostly used sanitation system in rural areas. In addition, large amount of investment needs to be subsidized from funding agencies and the required livestock at home are the common obstacle in practicing BI. In general, this is the case of all rural areas of Nepal. Therefore, the study can be generalized and used as the study of sanitation system in rural areas of Nepal.

Achieving sustainable sanitation practice is possible from USDT that provide promising benefit to the agricultural, environment, health and in urban areas as well with long term sustainability in Nepal. Government’s plan on sanitation also expect public health, economic growth, social inclusion etc. But mostly used conventional toilet system does not fulfil any terminologies stated above. If conventional toilet system is continued to use, centralized sewerage system has to be facilitated to the people in future which is expensive and not environment friendly.

Therefore, promotion of USDT in the user level is an approach towards sustainability. The concept of conventional toilet system should be replaced by the new ecological sanitation system as USDT. Government goal in achieving toilet coverage should incorporate USDT as a sustainable toilet system. Emphasis on USDT from all sanitation sector and research to make USDT user-friendly and appropriate in local cultural way is needed. Only then, long term benefit from sanitation can be expected.
Acknowledgement

I would like to express my sincere thanks to my supervisor Mr. Lars Hylander for being so kind and helpful throughout my project work. His suggestion over the time has made me reach the end of this project work. Otherwise, I would not have been able to write this thesis without his support. I also want to thank Mr Amrit K. Rai and Mr Guneshwor Mahato from Rural Water Supply and Sanitation Project in Western Nepal (RWSSP-WN) for giving me an opportunity to conduct my thesis. I must thank my entire friend who supported me throughout my study here in Uppsala.

I am deeply thankful to the Uppsala University.
Bibliography


Cordova, A. 2001. Large-Scale Dry Sanitation Programs, Preliminary Observation and Recommendations From Urban Experiences in Mexico. Human Dimensions Research Unit, Department of Natural Resources, Cornell University.


Hylander, L. (2006). Släng inte fosforn i siön (Don’t waste phosphorus into the lakes!). Forskningsnytt om økologisk landbruk i Norden, 4-6.


Annex

Annex 1

Weightage given to the objective, sub-objective, and attributes on GMAA model
Annex 2

Questionnaire Model

1. Participant Name  
   Male [ ]  Female [ ]

2. Current Sanitation Practice
   US [ ]  USFT [ ]  USDT [ ]
   BI [ ]  Conventl Latrins [ ]  None of them [ ]

   Technical

   Recycling Method

   3. Which of the following waste can easily be recycled to the fertilizer?
      Urine [ ]  Faeces [ ]  Urine and Faeces [ ]
      None of them [ ]  Biogas Integrated [ ]

   Storage space

   4. Have you had problem of space in storing Urine and Faeces?
      Yes [ ]  sometimes [ ]  No idea [ ]
      No [ ]

   Equipment Accessibility

   5. Which of the following equipments for sanitation practice you have heard of?
      Urine Separating [ ]  Urine Separating Dry Toilet [ ]  Biogas Integration [ ]
      None of them [ ]

   Gender Friendly Technology

   6. Which one of the following do you find more gender friendly?
      US [ ]  USFT [ ]  USDT [ ]
      BI [ ]  Conventl Latrins [ ]  None of them [ ]

   Userfriendliness

   7. Do you feel comfort in changing the position for anal cleansing?
      Yes [ ]  Might be [ ]  No idea [ ]
      Might not be [ ]  No [ ]
**Adequacy**

8. Do you feel you need support from different groups for your ecological sanitation practices?
- Yes
- Might be
- No idea
- Probably not
- No

**Stakeholders**

9. How much support do you think you have gotten from different stakeholders?

<table>
<thead>
<tr>
<th>Rank it</th>
<th>1-</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Social**

**Infectious susceptibility**

10. Use of water in sanitation will reduce the infectious susceptibility.
- Very True
- No Idea
- False

**Hygiene/Sanitation**

11. How hygiene do you think your current toilet practice is?
- Not Hygienic
- Partially Hygienic
- No Idea
- Hygienic

**Gender Equality**

12. Which sanitation practice brings both men and women at the same level of household working?
- US
- USFT
- USDT
- BI
- CL
- None of Them

13. Who is mainly responsible for most of the Household work? (Cleaning, Fetching water, Cooking)
- Men
- Mostly Men than Women
- Men and Women
- Mostly Woman than Men
- Women

14. Do you believe proper sanitation would reduce the fetching water quantity?
- Yes
- No Idea
- No
**Attitude**

15. Which one is more threatening and harmful?

- Urine than Faeces
- Faeces than Urine
- Both are threatening
- None of them

**Motivational**

16. Do you feel proud in practicing ecological sanitation?

- Yes
- No

17. Do you know about the linear flow of nutrient through the food?

- Yes
- No

**Behaviour**

18. Are you used to with this sanitation practice?

- Yes
- getting used to
- No idea
- not getting used to
- No

**Religious**

19. Should not we value our religious culture where we do not process human waste?

- Should
- Might value
- No idea
- Might not value
- Should Not

**Human Dignity**

20. Are you aware the sustainable sanitation practice where nutrient flow back to its original place farm?

- Yes
- Probably Heard
- No idea
- Probably Not Heard
- No

**Acceptability**

21. What do you feel about the processing of Urine and Faeces?

- Disgusting
- sometimes irritating
- No idea
- good
- Proud
- No
Environmental

Weather

22. Do you think that the weather plays a great role in fertilizing human waste?

Yes ☐ Might play ☐ No Idea ☐
Might not be true ☐ No ☐

humidity

23. Does humidity has any influence on the fertilization process of human waste?

Yes ☐ Probably Yes ☐ No Idea ☐
Probably Not ☐ No ☐

Precipitation

24. Do you think that Maximum Precipitation would be problematic in any sanitation practices?

Yes ☐ Probably Yes ☐ No Idea ☐
Probably Not ☐ No ☐

groundwater

25. Have you saved the ground water from polluting it?

Yes ☐ No idea ☐ No ☐

foulsmell

26. Does the foul smell from the toilets bother you?

Yes ☐ Sometimes ☐ No ☐

Surface water

27. Do you believe making use of faeces and urine in the field would reduce surface water pollution?

Yes ☐ No ☐

Soil type

28. Soil type does matter everytime on the use of fertilizer.

Very true ☐ Not always ☐ No Idea ☐
Might be ☐ Doesn't Matter ☐
Crop patterns

29. Are you aware of the fact that use of fertilizers is depends on the crop patterns we have in the field.

Yes        Not before        No idea
Probably not  No

Water requirements

30. Does human waste as fertilizer increase the water holding capacity of soil?

Yes        Probably Yes        No idea
Probably not  No

ECONOMICAL

Economic benefit

31. Do you believe human waste can be a source of income generation?

Yes        Probably Yes        No idea
Probably not  No

Market Linkage

32. How important do you think the role of different cooperatives in linking users and market?

Very Important        Important        No idea
Unimportant        No role play

Fuelwood saving

33. How do you find the idea of reducing fuel wood consumption with the use of proper sanitation?

Very Important        Important        No idea
Unimportant        No role play

Fossilfuel saving

34. Can we replace the use fossil fuel with the energy from human waste?

Yes        Probably Yes        No idea
Probably not  No

Electricity cost saving

35. Sanitation does even reduce the dependency on electricity?
Initial Investment

36. What Range of Money you can afford to install/Change the Sanitation Practice?

- 0-2000
- 2000-5000
- 5000-10000
- 10,000-15,000
- 15,000-20,000

Affordability

37. Are you willing to change more improved sanitation practices?

- Yes
- Probably Yes
- No idea
- Probably not
- No

Operation and Maintenance cost

38. What range of money you can spend for the operation and maintenance of the sanitation practice?

- 0-500
- 500-1000
- 1000-15000
- 15,000-2,000
- 2,000-3,000

Questions

39. Have you heard of Eco-sanitation?

- Yes
- No

40. Do you think that ecological sanitation is Sustainable Sanitation practice?

- Only recycling Urine
- Only recycling Faeces
- Recycling both Faeces and Urine
- None of them
- Biogas Integration

41. How disgusting do you feel for faeces? Rank 1 as very less disgusting and 5 for highly disgusting

1 2 3 4 5

42. How disgusting do you feel for Urine? Rank 1 as very less disgusting and 5 for highly disgusting

1 2 3 4 5
## Family Information

<table>
<thead>
<tr>
<th>Age</th>
<th>Number</th>
<th>Male</th>
<th>Female</th>
<th>Education</th>
<th>Work</th>
<th>Water-borne Disease infected/Year</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 15</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15 - 45</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt; 45</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Women Role**

**Men Role**

<table>
<thead>
<tr>
<th>Kerosene Use/ month</th>
<th>Fuel wood/month</th>
<th>Electricity/month</th>
<th>Food Availability</th>
</tr>
</thead>
</table>

**Food Availability**

<table>
<thead>
<tr>
<th>S.N</th>
<th>Farm Corps</th>
<th>Season Garden Crop</th>
<th>Season Garden Crop</th>
<th>Yield/Year</th>
<th>Local Price</th>
<th>Name of Fertiliser used</th>
<th>Fertiliser Used/Year</th>
<th>Price of the Fertiliser/kg</th>
</tr>
</thead>
</table>