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EDITOR'S NOTE

Alexandru-Ionuţ Petrişor, PhD, PhD, Habil.[1]

Since Ernst Haeckel defined it during mid 1800s, ecology encompassed studies of organisms in relationship with their living conditions and with other organisms, and of the organization (including components and relationships) and functions of communities and systems, such as the biogeochemical cycles and their relationship with the diversity and stability of the entire systems.

The energy crisis and theses phrased by the Club of Rome suggested new research directions, such as the impact of human communities on natural resources, pollution and environmental degradation, up to the global change, a new term designed to include land use, energy use, and climate change. Re-thinking socio-economic development to address environmental issues led to a new concept, sustainability, coined by the Brundtland Report. Research aiming to identify the concrete means for making socioeconomic development sustainable added new branches, including conservation biology, ecological design and economics, industrial, urban, and social ecology, but also theoretical and systemic ecology and many others.

The new directions evolved to a new science of sustainability, paralleled by the inter- and trans-disciplinary interchanges that connected ecology to other sciences, leading to the creation of an entire group of environmental sciences.

To address research carried out on all these topics and all other related ones the IAFOR Journal of Sustainability, Energy and the Environment (IJSEE) aims to become a flagship, publishing only the best articles in all subjects covered (sustainability, energy and environmental issues), including theoretical considerations, full and brief research reports, but also opinion articles, conference reports, extensive literature reviews and book reviews.

The articles will cover one or more of the following subjects: agroecology, aquatic and marine ecology, biogeochemistry, biogeography, community ecology, conservation biology, ecological anthropology, ecological design, ecological economics, ecological engineering, ecological succession, ecophysiology, ecotoxicology, energy, environmental psychology, environmetrics and quantitative ecology, evolutionary ecology, forest ecology, human ecology, hydrobiology, industrial ecology, microbial ecology, population ecology, restoration ecology, social ecology, soil ecology, sustainability, systems ecology, theoretical ecology, and urban ecology.

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We encourage submissions from all over the world, as long as they fit with the scope of the journal, the papers have not been published or submitted and are not considered for publication by any other journal, the research described by the paper is original, and the presentation of other materials does not violate any other author's rights, the contents of the paper is known and approved by all authors, who contributed to writing the paper and/or carrying out the research described, there is no inappropriate or offensive content, the authors assume the full responsibility for the contents, correctness and originality of the submissions, including plagiarism and auto-plagiarism, and the ethical constraints are observed (experiments involving human and animal subjects, etc.). The journal will observe a strict peer-reviewing procedure; no manuscript will be accepted or published without peer review. IJSEE will be published online and made freely available. Printed issues will also be produced. Neither editors nor authors are remunerated.

The creation of IJSEE has only been possible with the help of IAFOR, the International Academic Forum. I would like to thank the Executive Director of IAFOR, Dr. Joseph Haldane, for the fruitful discussions that helped drafting the vision on the mission and future of IJSEE. Last but not least, I would like to thank our Associate Editors, members of the Editorial Board, and people who declared their willingness to help as potential reviewers for their commitment and valuable comments that helped drafting our editorial policies and ensured a successful start on the way to achieving our goals.

Khan S.-A., Azad A. K. M. A. M. (2014), *Social Impact of Solar Home System in Rural Bangladesh [...]*, IAFOR Journal of Sustainability, Energy and the Environment **1(1)**:5-22.

SOCIAL IMPACT OF SOLAR HOME SYSTEM IN RURAL BANGLADESH: A CASE STUDY OF RURAL ZONE

Sabbir Ahmed Khan[1], A K M Abdul Malek Azad[2]

Abstract. The Initial research on the Solar Home System (SHS) was related to an evaluation of its present circumstances in Bangladesh. Afterwards, considering its increasing demand, a significant research study was conducted to find standardized qualification testing procedures for SHS components. Sequentially, the following research deals with the socio-economic impact and sustainable development in rural areas of Bangladesh using SHS. A combination of qualitative and quantitative methodological tactics, were used to provide descriptive evidence concerning electricity's impact on the assessable socio-economic data. Qualitative consultations with the specialists involved in the SHS propagation method, delivered overall information related to SHS packages and exposed the professional's individual opinion regarding socio-economic impacts of solar electricity in a rural part of Bangladesh. To finalize this information with field-level data, a pervasive household survey and individual short interviews with shop-keepers were performed in a rural area near Dhaka city. SHS's contribute to sustainable development mainly through the improvement of social aspects in rural life. The implementation of SHS's in rural Bangladesh, causes optimistic impacts, particularly in the areas of education, health, information, communication, social security and household works. Moreover, the plummeting of CO_2 emissions through the substitution of traditional lighting fuels has to be mentioned as a positive environmental impact. The economic impacts of the SHS's are limited to an increase in income of shops. Previously SHS's were mostly used by households who possessed high incomes however by now focusing on the poorer households has extended the opportunity of developing both socio-economic groups. During the last few decades, the implementation rate of SHSs are much notable than any other renewable energy system. This is especially so in rural areas. Showing the impact on rural development, this research will amplify the opportunity of SHS's in the long run having adequate government subsidy.

Keywords: Solar Home System (SHS), Social-economic impact, Rural development, Battery management, Level of satisfaction

1. Introduction

According to recent data, the Bangladeshi economy is quickly growing and poverty rates are tumbling (Khan et al 2012, Khan et al 2012, Hossain et al 2011). Numerical data reveals that the economy has grown at around 6% per annum & that poverty had dropped substantially from 45% in 2005 to around 30% by 2010 (Khan et al 2012). But at present the country is suffering from acute problems regarding its power supply (Islam & Islam 2005). The general lack of access to electricity imposes limits on the

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prospects of growth and increased welfare. The overall incidence of electrification for households is only 42%. About 81.4% of the total electricity generation depends on natural gas. The rate of increase in electricity consumption is 10% annually. At this rate, the proven reserve of natural gas may not last more than 10 years (Hasan et al 2012). In order to meet the target set by the REB (Rural Electrification Board), fossil fuel based power stations, presently generating electricity, cannot be just the only weapon. We need to find alternative electricity sources to satisfy demand (Islam & Mondal 2009). Under these circumstances, the Solar Home System (SHS) could potentially be a positive alternative in providing affordable electricity. Sunlight combines with two types of energy: light and heat. Both may be utilized directly or indirectly by converting them into electricity. Being a tropical region, Bangladesh is endowed with copious supply of solar energy. The annual amount of radiation varies from 1840-1575 KWh/m^2 which is 50%-100% higher than Europe. Consumption of only 0.07% of the radiation could meet the country's present requirement (Eusuf 1997). So, there are lots of possible benefits by properly using this energy source. Not just that, there are also ideas that the solar electricity may actually be supplied through the normal grid. However, to analyze the future prospects there is a need to evaluate the present scenarios of SHS. Certainly, based on the current social development impact of SHS, an efficient figure can be drawn upon to understand the upcoming energy crisis. That's why this research paper and analysis of its results is focused on the recent developments surrounding SHS and its social impact on rural life in Bangladesh.

2. Background

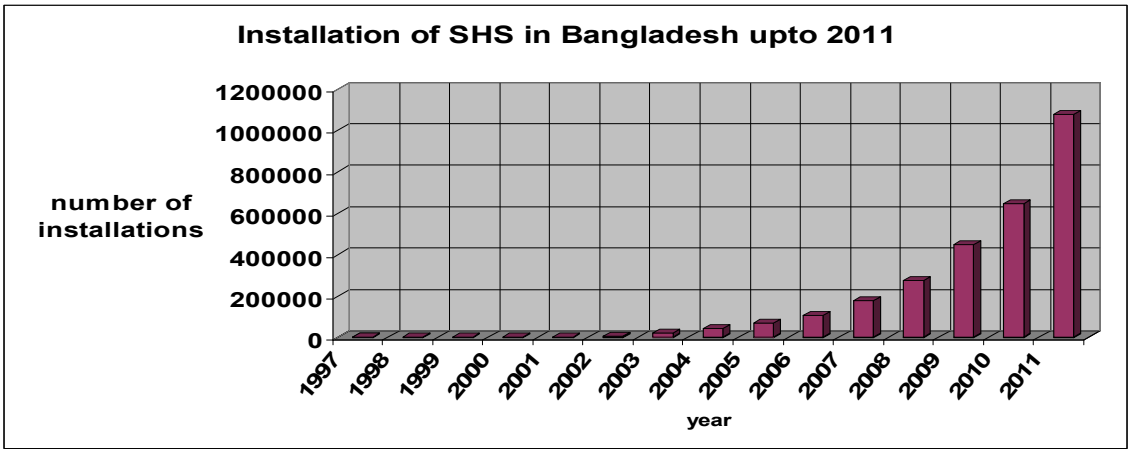

Figure 1. Exponential increment of SHS installation in Bangladesh.

The SHS industry in Bangladesh has since its inception in 2004 undergone strong growth. The number of partner organizations involved, have expanded from only a handful originally to current 30 organizations at present. During this time there has also been the advent of supporting companies who manufacture and supply batteries, charge controllers, lamp circuit etc. (Aziz & Chowdhury 2012). Figure 1 shows the number of SHS's installed over the last 15 years in Bangladesh. Moreover the SHS project in Bangladesh is managed by a financial institution established by the Government of Bangladesh the Infrastructure Development Company Limited (IDCOL). Currently every month around 60 thousand SHS units are being installed by IDCOL. According to recent data, (31August 2011 data) IDCOL has installed 1,073,872 SHS's. Their target is

to finance 1 million SHS's by the end of 2012 (Khan et al 2012, www.idcol.org). So now it is high time to measure the social impact of this budding market.

3. Methodology of Research

In the past several research projects have evaluated the solar home system operating in Bangladesh (Blunck 2007). However, the main focus of this research is to ascertain the proper social impact that has resulted from the use of SHS in rural areas. To do this the survey questionnaires submitted to households. They were patterned contrarily so they could imitate the meticulous impact of SHS. Figure 2 shows the tentative locations of studied area. The survey was conducted in the Gazipur (Kapasia, Lohadi) rural area, which is located near the city of Dhaka. It was envisioned that under examination the collected data would definitively define socio-economic conditions and provide an emblematic example of rural Bangladesh. The Kapasia area chosen for the research contains a huge number of villages, many of which do not have a grid connection. Following a provisional assessment it was clear that most of the population within the Kapasia area under consideration could afford a SHS as they are economically better off than other areas. Furthermore, their was the realization that solar home systems installed within the Kapasia area may play an imperative role in increasing the literacy rate amongst local people. The interviews conducted involved 25 household owners and 5 small grocery store owners. All the selected households were dominated the male member of the family.

Figure 2. Tentative Locations of the Study Village

3.1. Key Statistics of the Study Area

Kapasia has an area of 354.98 square kilometers. Kapasia has 11 unions and 231 villages, of which only two villages are urban with remaining 229 classified as rural.

The total population of Kapasia is around 385,580 and the literacy rate is 56%. Furthermore 70% of the people of Kapasia are residing abroad. For this reason Kapasia is economically stronger when compared to most other rural areas in Bangladesh. Additionally 20% of the people employed within Kapasia are either service holders, small businessmen, teachers, grocery shop owners, or work on poultry firms etc. 10% of the resident population live on farms and were ascertained as not being able to afford the Solar Home System. Key statistics of Kapasia Thana are given in the following Table 1.

Table 1. Kapasia Thana at a Glance for the Year 2009. (Source: BRAC, Kapasia Unit, Gazipur)

SL. No.	ITEM	STATISTICS
01	NO. OF UNION	11
02	NO. OF VILLAGE	231
03	TOTAL NO. OF POPULATION	385,580
04	NO. FO PRIMARY SCHOOL	225
05	LITERACY RATE	56%
06	NO. OF HOSPITAL	02
07	NO. OF BANK	09
08	NO OF BAZAR	55
09	ROAD IN KM (PACCA)	90
10	ROAD IN KM (KACHA)	238
11	NO. OF NGO WORKING	08
12	VGD CARD HOLDER	550
13	TOTAL AGRICULTURE LAND	64,960
14	NO. OF POND	2,260
15	TOTAL WATER BODY	825
16	NO. OF CHILDREN (0-15 YEARS)	75,821

BRAC has some criteria to select a location, which are:

- Grid connection will not reach by the next 5 years.
- High population density.
- Economically more or less sound.
- Number of markets and Bazar.

Kapasia fulfills all the criteria mentioned above thus it was selected as a project area in 1998.

3.2. Collection of Information

Information for the research was mainly collected by way of survey questionnaires conducted within households and at rural markets. To explore a more realistic portrayal or considered view of technical, social and economic aspects within the study area, the survey was carried out in those households that possessed solar home systems. The names of the property owner and the installation year of SHS were solely collected from selected village register books. To discover tangible views of SHS usage the survey was carried out from the village Lohadi under Barishabo union in Gazipur district servicing the SHS by BRAC. Figure 3 shows the Jamiratchor BRAC office.]

After collecting all the current data a mammoth study on the previous research work was then undertaken to also verify the deviation between the impact of present and

past results. This helped to provide an effective summary of the research work. The next section will concisely discuss the results and analysis.

Figure 3. Jamiratchor BRAC office Kapasia Gazipur

3.3. Types of Solar Home System

Table 2. Description of Solar PV Systems Provided by BRAC at Kapasia

Solar PV Module	Appliances	Components	Operating Time	Price (TK)
20 Wp	Two lamps of 8 watt	One module of 20 watt. One deep discharge battery of 47 Ah. Two charge controller. Two lamps of 8 watt. One structure, other accessories & installation.	4 hour per day.	10,500
40 Wp	Three lamps of 8 watt & one Black and White TV	One module of 40 watt. One deep discharge battery of 70 Ah. One charge controller. Three lamps of 8 watt. One socket for TV or mobile charger. One structure, other accessories and installation.	4 hour per day.	18,200
50 Wp	Four lamps of 8 watt & one Black and White TV	One module of 50 watt. One deep discharge battery of 80 Ah. One charge controller. Four lamps of 8 watt. One socket for TV or mobile charger. One structure, other accessories and installation.	4 hour per day.	22,500
60/65 Wp	Five lamps of 8 watt & one Black and White TV	One module of 60/65 watt. One deep discharge battery of 80 Ah. One charge controller. Five lamps of 8 watt. One socket for TV or mobile charger. One structure, other accessories and installation.	4 hour per day.	28,600
75 Wp	Six lamps of 8 watt & one Black and White TV	One module of 75 watt. One deep discharge battery of 98 Ah or 100 Ah. One charge controller. Six lamps of 8 watt. One socket for TV or mobile charger. One structure, other accessories and installation.	4 hour per day.	31,400

Four types of solar home systems are provided by BRAC. They mainly vary in size, capacity and price but their operating time remains constant. Table 2 gives a clear view about the available range of appliances and components for solar home system.

3.4. Sample Survey

The case study of three households and two grocery shops are included below:

Household 1:
Name of the Respondent: Md. Ainuddin.
Address: Village- Lohadi, Post Office- Gazipur, Union-Barishabo, District- Gazipur
Age: 50 Years
Education: Class 5
Occupation: Tailor
Monthly income: 5000 Taka
Family Members: 5 Number of person.
Previous kerosene consumption per month: 6 Liters
Mr. Ainuddin replaced four kerosene lamps and one car battery with solar home system. He is using the 75 Watt solar home system he is the most recent user and he did not have any complain with the system.
Average cost for lighting and entertainment of this family:
Initial cost:
Car battery: 2500 taka
Three kerosene lamp: 50*3 = 450 taka
Monthly expense:
Charging the car battery: 60 taka
Transportation cost for charging the battery: 20 taka
Kerosene cost: 6*46=276 taka
[Per litter kerosene cost=46 taka]
Mr. Ainuddin had to replace the kerosene lamp (Hurricane) every 4 years and he had to replace the Chimney every 6 months. The life- time of the car battery was approximately 3 years.
From the above analysis and from his personal opinion we can say that solar home system is a best solution and he is also being benefited financially as he can work extra one or two hours. Now his grandchildren get more time to study.

Household 2:
Name of the Respondent: Md. Shahidul Islam.
Address: Village- Lohadi, Post Office- Gazipur,Union-Barishabo, District- Gazipur
Age: 45 Years
Family Members: 5 Number of person.
Capacity of the SHS: 75 Watt
Previous kerosene consumption per month: 5/6 Liters
Md. Shahidul Islam has also replaced three hurricane lamp and one car battery with 75 Wp solar home system through, which he can run 6 light 10 Watt each and 1 black and white TV. He was using the system for about 2 years and left with few monthly installment of the cost. During these two years he had to change one lamp only and on the

components on the SHS was working fine. He was also satisfied with the service of the BRAC employee.

Household 3:
Name of the Respondent: Md. Shoriuddin.
Address: C/O Md. Shamer Ali Village- Lohadi, Post Office- Gazipur, Union-Barishabo, District- Gazipur
Age: 50 Years
Family Members: 6 Nos.
Capacity of the SHS: 50 Watt.
Previous kerosene consumption per month: 5 Liters
In this household they replaced two Kerosene lamp and one car battery by solar home systems. This family bought the Solar Home System on 22 December 2002. The system capacity is 50 watt. In these 7 years they only had to change the charge controller once. This is the only household we found who were using a DC fan. They were very satisfied with the overall performance of the system and they were also planning to buy another SHS.

Grocery shop 1:
Name: Md. Idrish Ali.
Address: Jolpai Tola Bazar, Village- Lohadi, Union- Barishabo, District- Gazipur
Age: 48
Occupation: Business
Monthly more income: 450 Taka
Monthly bill from another lamp: 150 Taka
Md. Idrish Ali installed the solar home system to run his business. He was using a 75 Wp SHS for one and half years. He said that he earns an additional 15 to 20 Taka more per day after the installation of SHS, because working time was extended two hours more. He was having some problem with the battery.

Grocery shop 2:
Name: Tara Mia Kholifa.
Address: Jolpai Tola Bazar**,** Village- Lohadi, Union- Barishabo, District- Gazipur
Age: 45
Education: Class 6.
Occupation: Business
Monthly more income: 400 Taka
Monthly bill from another lamp: 150 Taka
Tara Mia Kholifa was the oldest solar some user in the study area. He installed a 30 Wp solar home system in the year 1998. Except the solar panel he had replaced all the components once.

4. Results and Analysis

4.1. Average Income Condition and Ability to Afford SHS

Analyzing the surveyed data from Figure 4, it appears that the mean income of those families were not so high. More than 50 percent families' incomes were lower

than 7 thousands taka per month and only a few households are having more than 10 thousands taka per month.

According to this data, 48% of the households were regarded as low-income families. Most of them bought their SHS components with the help of an installation program offered by Partner Organizations (PO's). But due to the low household income it was difficult for them to pay the total amount installation cost. Therefore the feasibility of the monthly installment scheme with low interest. Good numbers of people like to go for the monthly installment rather than bearing total installment cost. According to the collected data, about 80% household installed SHS by monthly installment pattern.

Usually a range of solar panel types are available and offered for sale by the PO's. However, the most popular is the 50Wp solar panel. These 50 Wp solar home systems were also common in the studied area, which produced enough energy to run three lamps and one black & white TV system. The larger capacity systems (75Wp), were used by comparatively larger families (a higher income group per household) Although, 75Wp was also a popular options, greater numbers of households preferred to use the 50 Wp panel because of its lower cost and installation program. Table 3 shows the top two PO's 50 Wp scheme and Figure 5 shows the most used SHS.

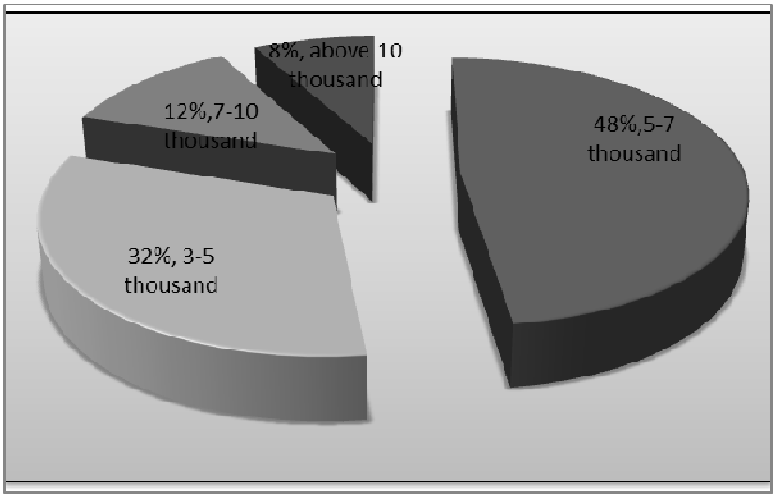

Figure 4. Range of income per month (Source: Author)

Table 3. 50 W panel system with load and price (www.gshakti.org, www.brac.net)

PO Name	System in Watt	Load Provided	Price
Grameen Shakti	50 Wp	4 Nos.7 watt lamp and 1 No 17" B/W TV point	26,800 taka
BRAC Solar	50 Wp	Four lamps of 8 watt & one Black and White TV	22,500 taka

Production of solar panels requires capital-intensive manufacturing facilities that are highly automated. At present Bangladesh is unable to manufacture the required PV modules and these are thus imported from outside countries (Islam & Mondal 2009). This is also true for high tech devices like LED's. Nevertheless, these high tech components are imported and assembled in Bangladesh by the Partner Organizations (POs) to produce the final device. For that reason the cost of components and installation is presents a high cost for those on minimum incomes. But a monthly payment program initiative from PO's has made it easier for some households to afford them. Still this is not

a common scenario, and the monthly payment and installment program together is still not sufficient enough to reach the poorest families. The high cost of acquiring a SHS's means that there is still a long way to go until electrification using SHS's will be available in every household within the Kapasia region.

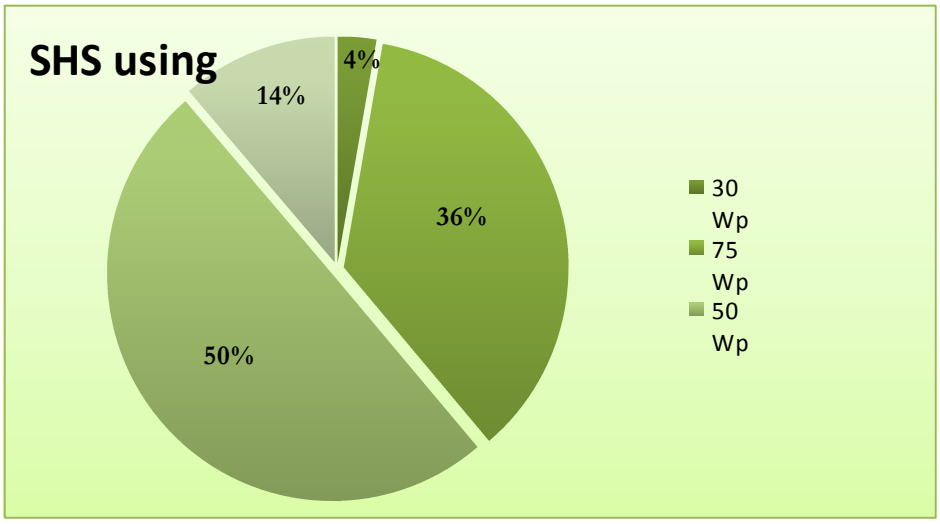

Figure 5. Most used SHS system (Source: Author)

4.2. Present Load Using Scenario and Increasing Obligation of SHS

Nowadays different electronic devices and equipment are very much familiar to people living regular lives even in rural areas. Table 4 shows the augmentation of electronic loads from last five years in the surveyed area. Figure 6 denotes the overall status of electronic load usage within the 25 families surveyed from products such as electric lights, mobile chargers, fans, radios, TV's (Black and White), Refrigerators etc. In addition, Table 5 shows the Period of Daily Energy Consumption for Lighting and Entertainment with respect to hourly usage.

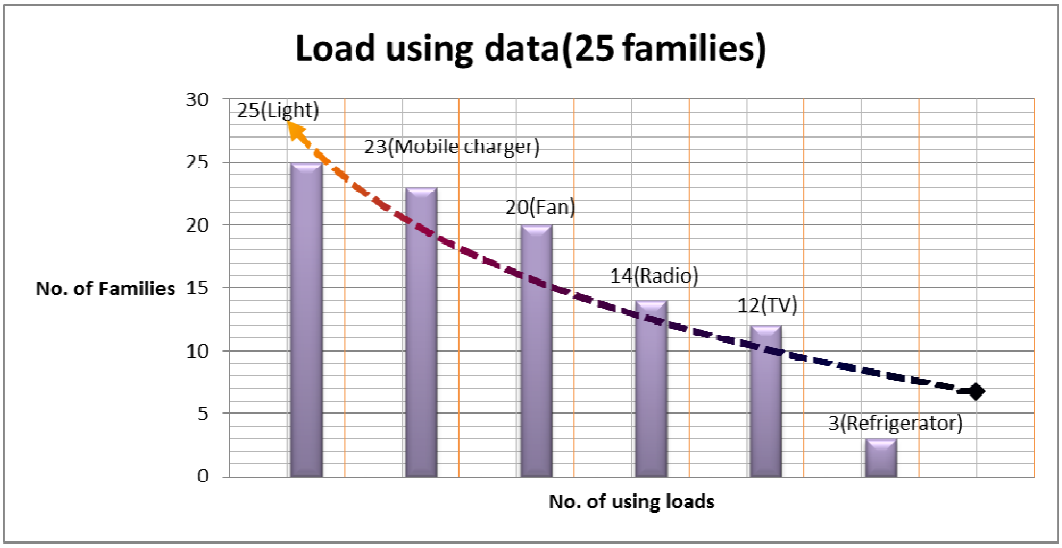

Figure 6. Load using data of 25 families (Source: Author)

Results from the household survey revealed that most of the families were using light, mobile chargers, fans and radios more than other electrical items. Radios are found particularly in the grocery stores where people usually spend their free time to gossip with neighbors. Nearly 50% of the families surveyed had at least one B/W TV in their home. Refrigerators were yet not so common. However there were still some families who possessed a refrigerator and the wider usage of them was increasing in line with the growing prosperity of families. While investigating household incomes, it was found that refrigerator ownership was more likely to be affordable amongst households that had an income greater than 7000 Taka.

As discussed earlier government reports have found that poverty levels have been decaying over the last 15 years. The increasing usage of electronic goods in daily life also reflects the validity of this government report. This therefore indicates that in spite of having low supply of electricity from the national grid such a newly developed life style is really only possible due to the growing us of SHS's.

Table 4. Increased number of electronic materials in our rural area in last 10 years

House Hold No.	2002- 2005						2006-2012					
	Light	Fan	Mobile charger	Radio	TV		Light	Fan	Mobile Charger	Radio	TV	
1.	Yes	No	No	No	No		Yes	Yes	Yes	No	No	
2.	Yes	No	No	No	No		Yes	Yes	No	No	No	
3.	No	No	No	No	No		Yes	Yes	Yes	No	No	
4.	Yes	No	No	No	No		Yes	Yes	Yes	No	No	
5.	Yes	Yes	Yes	No	No		Yes	Yes	Yes	Yes	Yes	
6.	Yes	Yes	Yes	No	No		Yes	Yes	Yes	Yes	Yes	
7.	Yes	Yes	No	No	No		Yes	Yes	Yes	Yes	Yes	
8.	No	No	No	No	No		Yes	No	No	No	No	
9.	No	No	No	No	No		Yes	No	Yes	No	No	
10.	Yes	Yes	No	No	No		Yes	Yes	Yes	Yes	Yes	
11.	Yes	No	No	No	No		Yes	Yes	Yes	Yes	Yes	
12.	Yes	No	No	No	No		Yes	Yes	Yes	Yes	Yes	
13.	Yes	Yes	No	No	No		Yes	Yes	Yes	No	No	
14.	Yes	Yes	No	No	No		Yes	Yes	Yes	Yes	Yes	
15.	Yes	Yes	No	No	No		Yes	Yes	Yes	Yes	No	
16.	Yes	Yes	Yes	No	No		Yes	Yes	Yes	Yes	Yes	
17.	Yes	Yes	Yes	Yes	No		Yes	Yes	Yes	Yes	Yes	
18.	Yes	Yes	Yes	No	No		Yes	Yes	Yes	Yes	No	
19.	Yes	No	No	No	No		Yes	Yes	No	No	No	
20.	Yes	Yes	No	No	No		Yes	Yes	Yes	Yes	Yes	
21.	Yes	Yes	Yes	No	No		Yes	Yes	Yes	Yes	Yes	
22.	Yes	Yes	Yes	No	No		Yes	Yes	Yes	Yes	No	
23.	No	No	No	No	No		Yes	No	Yes	No	No	
24.	No	No	No	No	No		Yes	No	Yes	No	No	
25.	Yes	No	No	No	No		Yes	Yes	Yes	No	Yes	

Table 5. The Period of Daily Energy Consumption for Lighting and Entertainment.

Consumption	Morning	Afternoon	Evening	Night
Lighting	-	-	6pm-7pm	7pm-10pm
TV			3:30pm-7pm	7pm-9pm
Radio	7am-8am			

Conventional Energy Sources in the Study Area other than SHS:

Candles: Some of the people in this area were using candles for lighting. Mainly business people were using candles for emergency lighting and students were using candles before examination, at least 2 hours in the night. The average price of a candle in this area was 2 Taka.

Hurricane (Kerosene Lamps with Chimney): For domestic lighting this type of lamp was the most widely used form. This type of lamp was more preferable than candles and wick lamp because it produces more light. One kerosene lamp with glass chimney costs around 120 to 200 Taka.

Torches: This type of flash-light was widely used for communication to the out-doors or for intermittent indoor use, usually powered by 2 or 3 dry cell batteries, which was not in any way rechargeable.

Car battery: For entertainment purpose some people used to use car battery. To watch a black and white TV for about one hour they had to recharge a car battery twice a month and to do that they had to spend approximately, 200 taka per month.

Nowadays those conventional energy sources are not as popular as before. One of main reasons is increasing demand of SHS's.

Table 6 includes the rural electric load usage data of Bangladesh. Actually within rural areas, all these loads are not used constantly. There are some particular times of the day when loads vary. This research has also focused on timing of usage loads.

Studying Table 6, it can be summarized that the average daily electricity requirement for one household is 156 Wh.

Table 6. Daily Typical Energy Requirement for Lighting and Entertainment.

Appliance	Power (W)	Duration (Hour)	Energy (Wh)
Lamp 1 (reading and bed room)	6	5	30
Lamp 2 (bed room)	6	4	24
Lamp 3 (bed room)	6	2	12
Radio	10	1	10
TV(Black and white)	20	4	80

4.3. Problems of Households and Contribution of SHS on Social Life Changing

Having undertaken an overview of total electrical system in the designated rural area, now it's time to have an appropriate comprehension on the regular problems that the residents are facing and how SHS can contribute to solve these problems. Though poverty conditions in Bangladesh are reducing day by day the overall living standard and per capita income of the country is still low. People living in rural areas still face difficult conditions in their daily lives having to find basic items such as food and clothes as well as not being connected to the electricity grid. The financial difficulties facing people in Bangladesh is the countries foremost problem. The lack of access to electricity is also a crucial problem particularly in respect to people living in rural areas. For this reason the identification of these problems during the survey stage took a vital place in this research.

Figure 7 entails the actual phenomena of our rural area's problems. About 28% of problems occur due to the lack of proper electricity, particularly where there is no grid electricity. It also looks improbable to expect grid electricity throughout the whole country knowing our limitations of resources. Hence, Solar Home System (SHS) can play an obvious role where there is no grid electricity connection. SHS can provide access to electricity at a low cost and without distorting the environment. Therefore SHS can dramatically improve the lifestyles of rural people in Bangladesh. Figure 8 designates some of the regular activities that are frequently undertaken by people with the help of a SHS unit in their household, thus demonstrating that this technology has made the lives of these rural people far more active and easier than before.

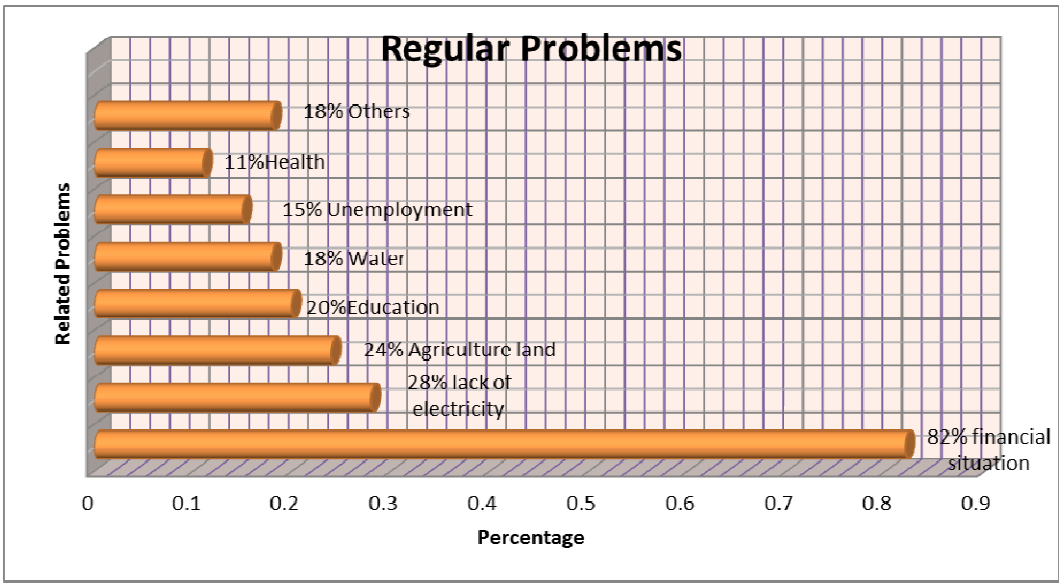

Figure 7. Focal problems of the households (Source: Author)

To reveal the subjective impressions of SHS users with respect to the socio-economic impacts of their systems, they were asked about changes in their daily lives following the installation of their system in their household. Figure 9 reveals the surveyed result, and gives a clear understanding of the positive social impacts that SHS has provided in rural Bangladesh. Now the target is to find the reasons why people are getting more interested with SHS. So the next conducted data is based on the reasons behind the public popularity towards SHS. In the investigation, the people were asked about the socio-economic impact of the SHS. Our motive was to identify the changes that SHS brought to them. The study detected many factors that bought changes in the daily lives of households. For example people are receiving better entertainment facilities with the help of SHS. That access to entertainment brings changes in lifestyle to rural people. Rather than gossiping with neighbours, ideally people now prefer to watch many of the TV shows now available and gain further knowledge. It assists people to keep in step with the modern world and also know about current world events. Due to have lighting facilities in the home, children can now have more time to study. Farmers can now work longer hours in the field. Better lighting facilities have also changed the daily routine of females in the household. These days they don't have to depend on just on sunlight to complete their household chores. Daily communication is also no longer a

big deal for the rural areas people. With the help of mobile phones and better lighting facilities they can move easily anywhere they need to, not only physically but also virtually. Actually, they feel their own lives offer more security. In summary, the standard of our rural areas people has increased with the positive impact of SHS.

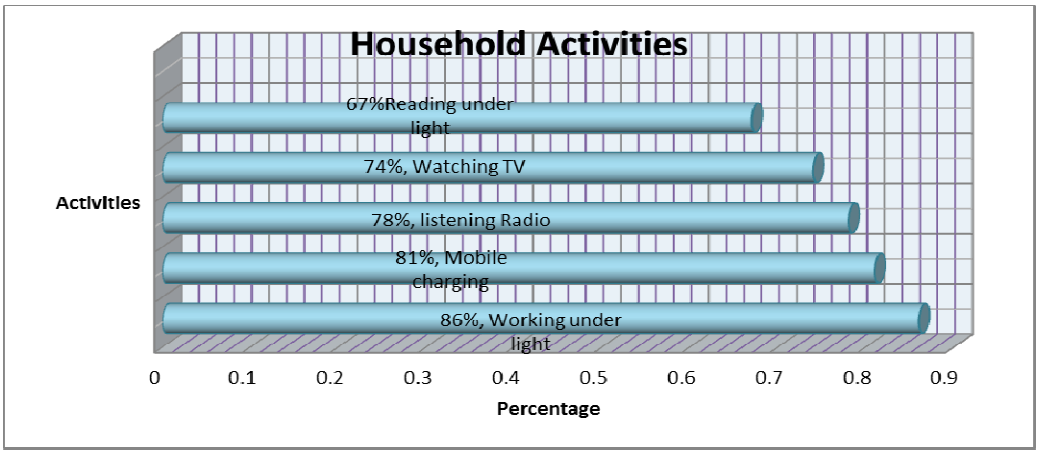

Figure 8. Electricity consuming activity through household (Source: Author)

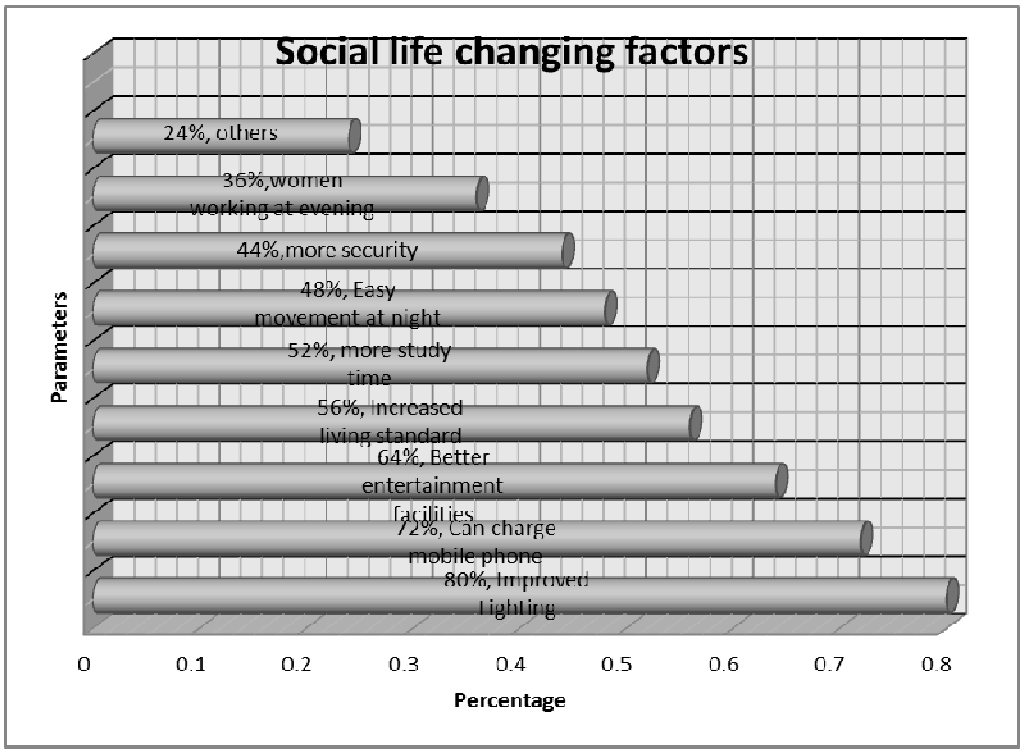

Figure 9. Daily life changing by SHS (Source: Author)

Better opportunities for information and entertainment were perceived as important changes by 64% of SHS households, followed by improved lighting conditions (80%) and thus easier movement in the house at night (48%). As another benefit of lighting, the improved conditions for studying by school children were quoted in 52% of SHS households. Other frequently mentioned changes include the possibility to charge mobile phones (72%), an overall increased living standard (56%), increased se-

curity due to household lighting (44%), and facilitated household work in the evening hours (36%).

Another motive of this exploration was to find the most benefited household members following the introduction of SHS into the household. According to Figure 10, the results assess that the most benefited members are women. Actually they are assisted in many activities by the availability of SHS. They are provided with entertainment in the evening through watching TV. Through this they are also educating themselves and advancing their personal knowledge of the world outside their home or village. Many of them are also listening to radio. Children are also very much benefiting as their activities increases. They are having chance to grow up like town kids. Most of all, women and children have noticed the improved security conditions following the introduction of SHS into the household.

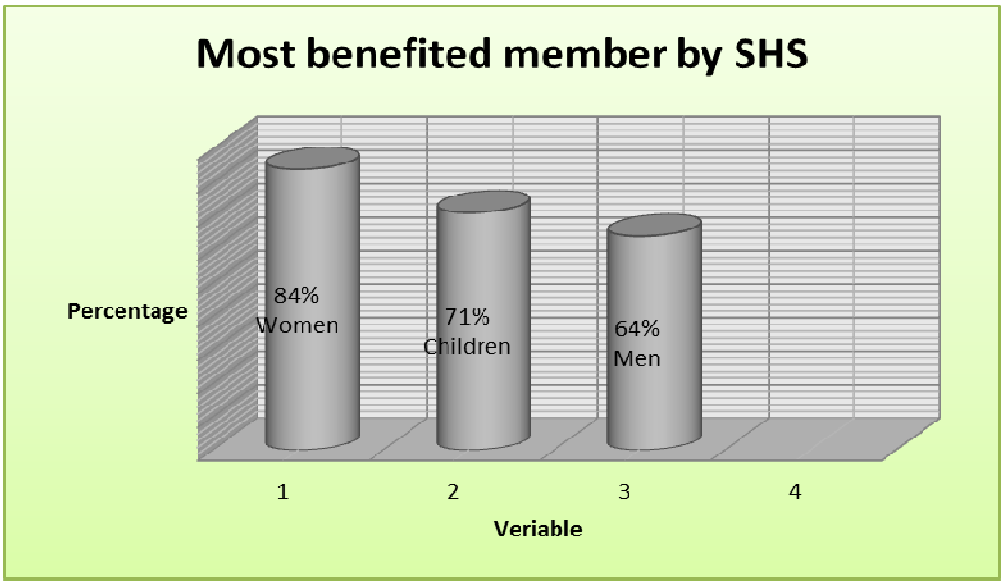

Figure 10. Most benefited member. (Source: Author)

4.4. Level of Satisfaction

Gradually, SHS is becoming a priority for the rural people. But due to the high installation price many people are still not that much interested to purchasing a SHS for their home. In addition, some people report that they are not enough satisfied with the service of the SHS organization. Still the results generally reveal that overall users of SHS are satisfied with the service they are getting. Figure 11 compares the satisfaction levels of SHS users taken from the conducted survey report. Also comparing the Michael Blunck Report of 2006 (Blunck 2007) it seems quite clear that SHS is gradually becoming a both a popular item and has name recognition amongst rural people in Bangladesh. Figure 11 outlines the positive improvement stemming from SHS usage over the last 6 years. This improvement has gone from 35 % (2006) to 52% (2012) according to results reported in our survey.

4.5. Damaged Battery Management

Towards the end of the survey, battery and charge regulator related questionnaires were asked of each household. This was due to their short warranty periods and that people need to change these items after certain period of time. Each PO's have their own program to teach people what to do with those damaged or worn out components. The survey was conducted from the 25 families along with the 5 grocery shops to find out what they actually did with those damage components. Most of them returned the items to the NGO after using them, but not all. Some of them throw the items out, which might possibly be very harmful to the environment. According to Figure 12, the 32% of people who indicated that they threw out worn or broken components is a matter of concern. This is because this percentage will be likely to increase further in the years ahead with the growing numbers of families using SHS and may result in a more threatening and hazardous environment in the near future.

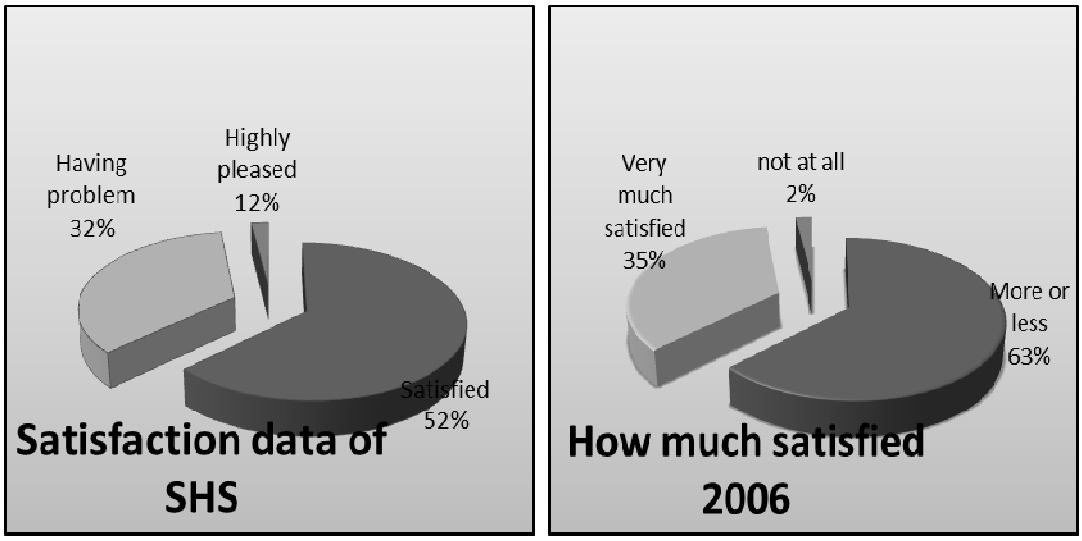

Figure 11. Comparison of satisfaction data 2006 and 2012 (Source: Author)

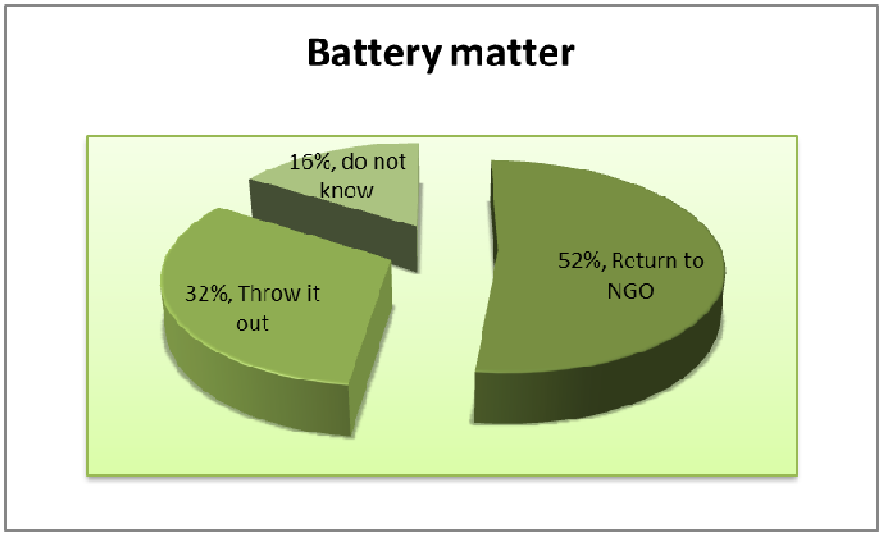

Figure 12. Management of damaging battery (Source: Author)

4.6. Need of Standard Qualification Testing

Standard component testing is badly needed nowadays. Due to the numerous manufacturers (local and foreign) the resulting device contains components that differ greatly in all parameters. As a result the overall quality varies from organization to organization. This unstable quality is increasing with the increase number of SHS installation and thus the system inefficiency. Maintenance of a standard quality will increase the life cycle of SHS and also make SHS more feasible for future. According to the synchronous research work reference paper (Khan et al 2012) is focused on standard qualification testing procedure and its impact on Bangladesh. Maintaining this qualification testing will result less discarding of components and tossing less e-wastage.

4.7. Need of Proper After-Sales-Services

In area surveyed the after-sales services are provided by BRAC solar and also by Grameen Shakti. However, 17 of the surveyed households were not satisfied with this service. According to SHS owners the main problem is related to the frequency of response; meaning technical services are not regular enough. Manpower is another notable obstacle for services. There are not enough technicians to support after-sales services. Again, there are further complaints regarding unskilled technicians. This reveals that skilled technicians need to be provided for and confirmed by the provider company. In fact, SHS is a totally interlocked system; if one of the devices components becomes damaged somehow, then the whole system becomes worthless. Unless the device is repaired by service center, owners are unable to get electricity from SHS. If the service issue is not improved then it may have an adverse effect on the SHS growing market. Furthermore, customer training should be included in the after sales service. About 50% of the SHS owners surveyed were not technically sound and they even don't know how to use it. For even the most minor technical problems the customer has to rely on the technical support services. This becomes annoying for both customer and seller. Many don't touch the system due to the fear of electric shocks. Moreover they are afraid of cleaning the panel on the SHS with dry cloths. As a result, basic training on SHS components and their operation should be included as part of the after sales service so to ensure safe usage.

5. Conclusion

The last 14 years of data shows that both rural and urban people prefer SHS as an effective alternative in providing energy for homes and businesses (Khan et al 2012). The effect on the rural population is more perceptible than on the urban as more people are aided by its capability. As mentioned before the poverty levels in Bangladesh have just started to fall. However this situation will remain uneven for sometime until both the rural and urban expansion in the economy are able to march on the same line. According to research results, SHS has started this revolution in the rural part of the Bangladesh economy and the satisfaction levels for it are quite high (Figure 11). But the main drawback is related to the income levels and the SHS price. According to the Figure 4, 48% of families have very low incomes, which means that they are unable to afford buying an SHS directly. Even paying by a monthly installment scheme is hard for them. Therefore, the government should give enough subsidies to keep the SHS price low. On

the other hand, the developing effect of SHS is not only beneficial on economic point of view but also with respect to its social impact such as improving living standards, and the new ways of thinking and gaining entertainment and so on. Nowadays, the work schedules of people in the surveyed area people increased by 86%. This is very positive sign for country's economy. Moreover, a 67% increase in the available reading times of students is a perfect example of increased development in living standards. Finally, this research indicates that woman are benefiting the most from having SHS's in their households as it improves their conventional life style, fives them the feeling of greater safety, allows them to have more entertainment choices, and take greater part in the economic activities near their home such as grocery shopping. Nevertheless, in spite of having so many advantages there are still some environmental menaces surrounding SHS usage such as the disposal of damaged batteries. The increasing numbers of SHS's used in Bangladesh will mean that an enormous number of damaged batteries will need to be disposed of thus consequently leading to a gigantic environmental hazard in the years ahead. Nonetheless, the environmental management of these batteries has become a very important topic to conduct future research. This has already started.

Acknowledgement

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THE IMPACT OF TOURISM DEVELOPMENT ON THE STRUCTURE OF AGRICULTURAL LANDSCAPE OF THE DONGSHAN RIVER BASIN, TAIWAN

Wen-Pin Lin[1], Shu-Chun Huang[2]

Abstract. After the establishment of the Dongshan River Scenic Area of Yilan County in Taiwan, land use in the Dongshan River Basin has undergone dramatic change, from agricultural areas to recreational settings, in the past decades. The purpose of this study was to apply the approach of landscape ecology to analyze the spatiotemporal transition of the agricultural landscape of the river basin after tourism development. The study aimed to examine the landscape change in the river basin and its ecological implications. Maps of the Dongshan River Basin in 1987 and 2003 were generated, and the land uses were grouped into six land-use types: paddy fields, high-density vegetation, low-density vegetation, water, built-up land, and sandy beaches. A set of landscape metrics were computed with FRAGSTATS. The results showed that, from 1987 to 2003, the major change in the river basin landscape was a rapid increase in the area of built-up patches, while the areas for all other land use decreased. As for paddy fields, although their overall structure was not significantly altered over the study period, 5% (301 hectares) of the paddy fields had been replaced by urban settlements, which included the river park, the booming country house scene, and a traditional arts center. These changes were the main contributors to the increasing patch edge of paddy fields. Viewing paddy fields in Dongshan River Basin as unique man-made habitats, attention is then given to both the dispersion of built-up patches and the increase in size of the patch edge of paddy fields.

Keywords: Tourism development, Paddy fields, Landscape ecology, Land-use changes, GIS

1. Introduction

As the economy develops rapidly, it accelerates changes in land use. The landscape is transformed and the original characteristics of the environment are altered (Harren, 2002). Change in land use can have a significant impact on the surrounding ecological environment; therefore, it is necessary to understand the spatial dynamics of an ecosystem to ensure its ecological functions (Fang *et al*., 2005). Landscape ecology has become the fastest growing sub-discipline of ecology, ever since Carl Troll, a German geographer, first proposed the concept in 1939 (Wu, 2003). It has been extensively applied to explore the relationship between land-use changes and ecological processes in specific ecosystems. Over the past decades, the approach of landscape ecology has been applied to a wide range of problems, including the change of a single landscape pattern,

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landscape and biodiversity protection, nature reserve management, and urban planning. It provides an important methodology for studying the relationship between land use and ecological consequences. By using quantitative methods, it allows the analysis of the spatiotemporal transition of a landscape pattern or ecological processes (Turner and Gardner, 1991).

Since landscape pattern has been linked to biodiversity and other ecological values of landscapes, changes in a landscape can be regarded as an integrative tool for assessing ecological sustainability (Renetzeder *et al*., 2010). Landscape fragmentation is the main consequence of the disturbing process of land development on ecosystems. It can be induced by either natural or human agents, and has a negative impact on many species of plants and animals and on ecological processes (Farina, 1997). It increases the vulnerability of isolated patches to external disturbance, and threatens the sustainability of habitats and biodiversity (Nilsson and Grelsson, 1995). Hemeroby (naturalness), defined as the magnitude of the deviation from the potential natural vegetation as influenced by human activities, is another important concept for describing ecological sustainability (Renetzeder *et al.*, 2010). Human influences tend to result in a simplification and geometristation of landscape structure that reduces biodiversity and adversely affects ecological sustainability (Peterseil *et al*., 2004; Zechmeister and Moser, 2001). As Weins (2002) points out, all of the central themes of landscape ecology apply equally to terrestrial and riverine ecosystems. He asserts that whether the change is on land or in aquatic systems is of minor importance in the context of landscape ecology, and it is the spatial patterns and processes that are important.

Agriculture is usually viewed as one of the major threats to hemeroby and biodiversity in Europe, whereas agricultural land use may provide benefits to biodiversity conservation and ecological sustainability in Asia. The rice paddy, the dominant agricultural land-use in monsoon Asia, is considered a form of "man-made" wetland, providing the benefit of multi-functionality. Wise use of rice paddy fields can partially compensate for the loss of natural wetlands (Yoon, 2009). Paddy fields can provide significant ecosystem services just as wetlands do. In Japan, the ecosystem services of paddy rice cultivation were estimated to US$72.8 billion (Science Council of Japan, 2001; cited in Natuhara, 2013). The ecosystem services of paddy field include supplying wildlife habitats, supporting migratory bird species along their flyways, recharging the groundwater, retaining storm water and aiding flood control, air purification and cooling, the prevention of soil erosion and landslides, and the reduction of carbon dioxide (Huang *et al*., 2006; Kato *et al*., 1997; Liu *et al.*, 2010; Wu, 2011; Yoon, 2009).

In Taiwan, as a result of the pressure from urban growth and competition from other land use development, the area for paddy fields has been decreasing in size. The total area of paddy fields in Taiwan decreased from 472,759 ha (1991) to 406,064 ha (2011), showing a 14% decrease over two decades (Council of Agriculture, 2010). Yilan County, an agricultural area located in the northeast of Taiwan, has been famous for its vast expanse of paddy landscape. However, the landscape has changed significantly in recent years due to tourism and housing development. One of the most significant cases is the change of the paddy landscape along the Dongshan River which was notorious for its frequent floods before the 1970s. After a river reconstruction project along its middle and downstream sections, the vicinity of these river sections was established as the Dongshan River Scenic Area in 1984. The Dongshan River Park, located within the scenic area, was opened in 1994; and the Yilan government further held the International Children's Folklore & Folkgame Festival on the park in 1996. The park soon be-

came one of the most popular tourist destinations in Taiwan, and boosted the local economy significantly (Yilan County Government, 2002). The county was then transformed from a production-based agricultural environment into a tourist-oriented recreational setting. An evolution in economies and industry reflects the common development and evolutionary process of humans and landscapes (Naveh, 1995). In addition, the progression of a society often accompanies shifts in land use and changes in local landscape, resulting in changes to the original environmental characteristics (Haaren, 2002). Following the establishment of the Scenic Area, waves of land policy and landscape reforms had a far-reaching impact on the spatial and landscape characteristics of the area around the river basin, dramatically changing land use. Apart from the consideration of agricultural production, the preservation of the ecological, aesthetic, and cultural values of agricultural land in the basin has drawn much attention from the public.

As Apan *et al*. (2002) have pointed out, landscape structure is the result of the interactions between physical, biological, political, economic, and social driving forces, and changes in a landscape regarding the anthropogenic influence (e.g., agriculture) are a key indicator of sustainability. Rather than imposing a negative impact on ecological environments, the paddy fields in monsoon Asia can benefit sustainability. From the aspect of ecological sustainability, attention must be paid to the change in land use in the Dongshan River Basin and the environmental issues involved. The purpose of this study was to apply the approach of landscape ecology by conducting a GIS-based analysis of the spatiotemporal transition of land uses in the Dongshan River Basin after a period of tourism development in order to examine the whole landscape change in the river basin and to explore the implications for agricultural land management.

2. Methods

2.1. Study Area

Yilan County, located in the northeast part of Taiwan, rapidly transformed from an area based on agriculture to one based on tourism. The most obvious evidence of this was the development of the Dongshan River Basin into a scenic area. The Dongshan River Scenic Area was developed by transforming the areas along the upper, middle, and lower sections of the Dongshan River as the Forest Park, Water Park, and River Park, respectively (Wujie Global Information, 2012). The region along the middle and lower sections of the basin, where the River Park and the National Center for Traditional Arts were located, accommodates the most popular tourist destinations in Yilan County. The study area includes the middle and downstream areas of Dongshan River (Figure 1).

Dongshan River, with a length of 25.3 km, is the fifth longest river in Yilan County (Yilan County Government, 2002). The river basin contains some of the richest farming land in Yilan County. This area consisted mainly of agricultural areas for rice cultivation before the development of the River Park in the 1990s. It flows northeastward through the Lanyang plain before emptying into the Pacific Ocean. Elevation ranges from 3 to 15 meters above mean sea level. The existing landscape of the basin is made up of paddy fields, patches of vegetation, fish ponds, and other land uses such as recreational areas, industrial parks, and residential settlements.

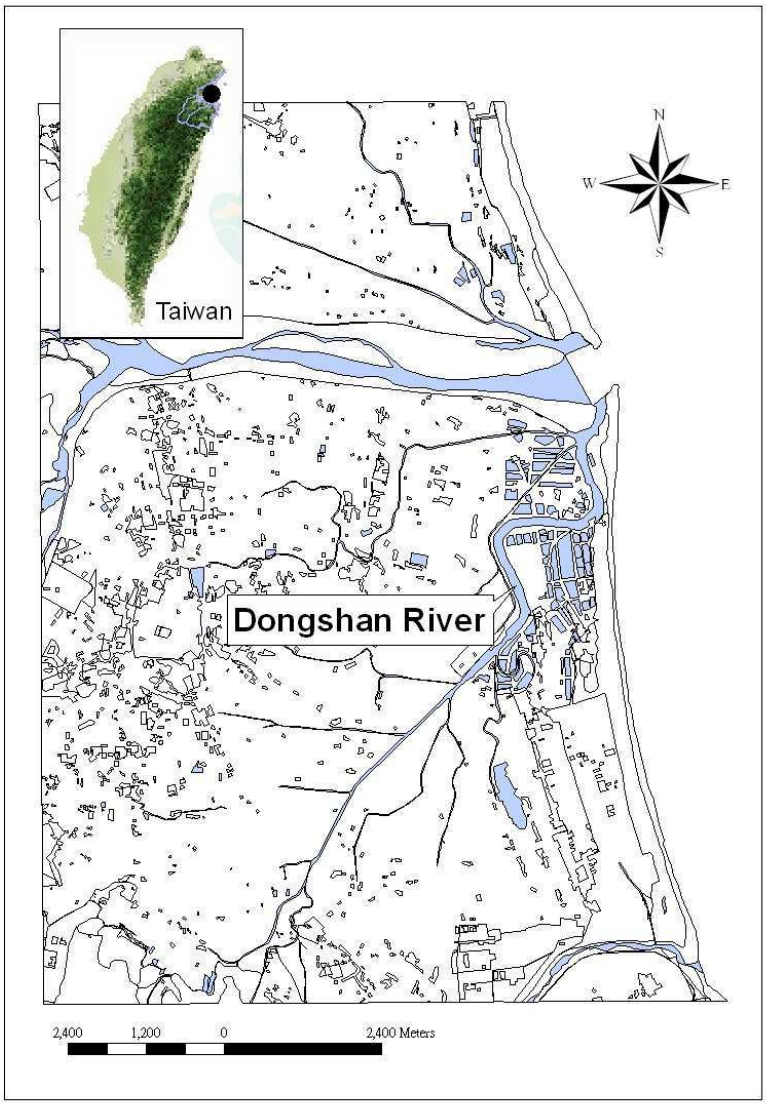

Figure 1. Location map of the study area

2.2. Data Acquisition and Processing

Since satellite images of the study area before the opening of the Dongshan River Park were not available, the hard copies of basic topographic maps, provided by Taiwan's Ministry of the Interior, were used as a data source for this study. These maps were produced with the orthographic projection methodology of analytical photogrammetry (Ministry of the Interior, 2011). With a scale of 1/25,000, these maps show not only the topography but also the different land usage in the area. Four versions of basic topographic maps were available for the study area. The first and last version, produced in 1987 and 2003, respectively, were selected as the data maps for the analysis of land use changes in the Dongshan River Basin.

The two hard copies of basic topographic maps were both digitized and converted into vector images with ArcView 9.0. According to the land-use information shown on the basic topographic maps, land use in the Dongshan River Basin includes: paddy fields, woods, wind-breaking forests, bush, dry farms, rivers, fish ponds, built-up

land, and sandy beaches. Usage was further divided into six land-use types (Table 1): paddy fields, high-density vegetation, low-density vegetation, water, built-up land, and sandy beaches. Woods and wind-breaking forests were included in the land-use type of high-density vegetation (2), representing that these areas are mainly covered by trees. Bush and dry farms were included as low-density vegetation (3), and rivers and fish ponds were included as water usage (4). The land-use maps of 1987 and 2003 were generated as shown in Figures 2 and 3. They were further converted into ArcGrid format for metrics computation with FRAGSTATS (McGarigal *et al*, 2002), which is a computer software program designed to compute landscape metrics for categorical map patterns, and can work with the program Spatial Analyst (an extension of the ESRI ArcGIS system) to generate landscape indices.

Table 1. Land-use types

Type	Land use
1	paddy field
2	high-density vegetation (woods and wind-breaking forests)
3	low-density vegetation (bush and dry farms)
4	water (rivers and fish ponds)
5	built-up land
6	sandy beaches

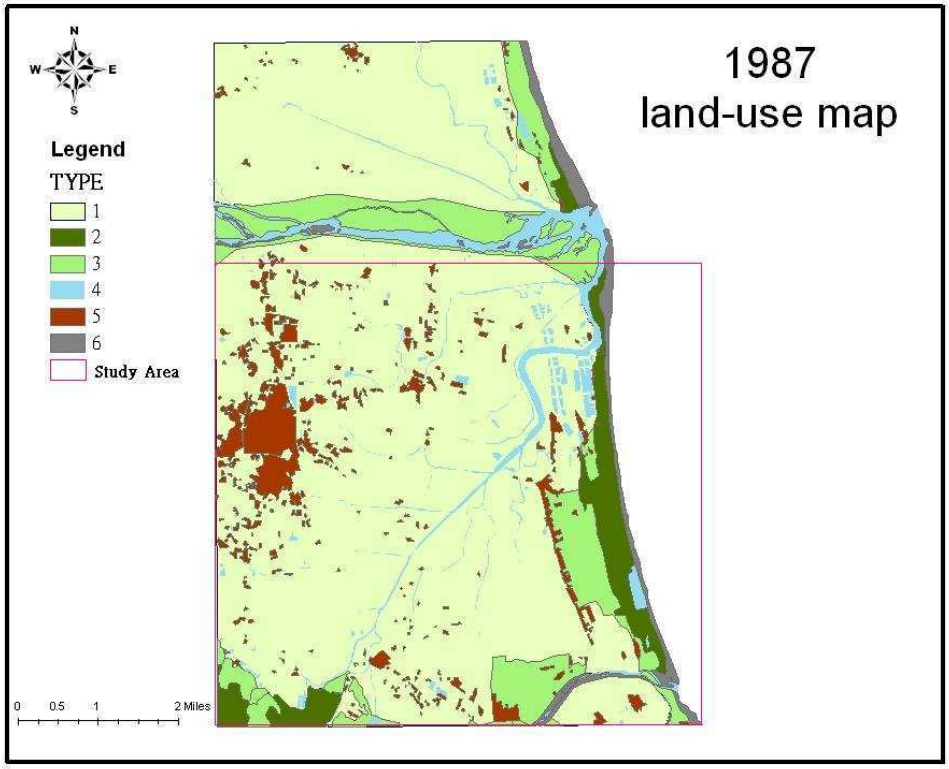

Figure 2. Land-use map of the study area in 1987

2.3. Analysis

A set of landscape metrics were computed with FRAGSTATS to conduct an analysis of the land-use changes in the Dongshan River Basin. Landscape metrics may be defined at three levels: patch, class, and landscape level. Patch-level metrics quantify the spatial character and context of individual patches; class-level metrics separately quantify the amount and spatial configuration of each patch type; and landscape-level metrics illustrate the spatial pattern of the entire landscape mosaic (McGarigal *et al.*, 2002). This study placed emphasis on class-level metrics as they can be utilized to quantify the extent and fragmentation of each patch type in the landscape. The computed metrics were selected from the group of area/density/edge metrics, which provide fundamental and valuable information for interpreting landscape fragmentation and structural change.

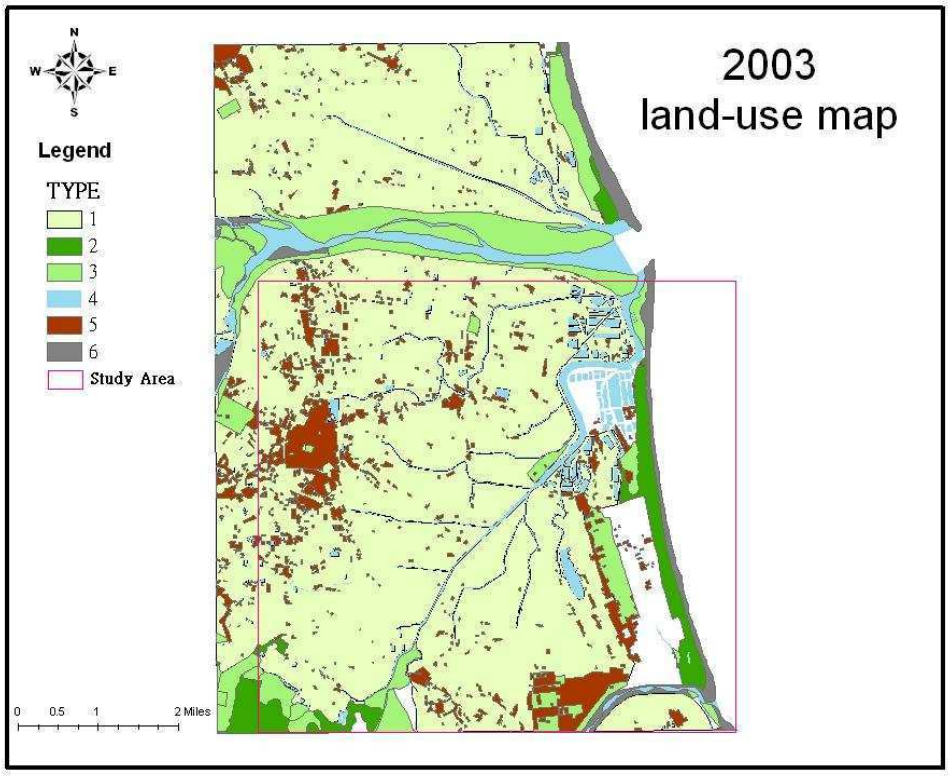

Figure 3. Land-use map of the study area in 2003

3. Results

3.1. Overall land-use changes

As shown in Table 2, all land-use types, with the exception of built-up land, have decreased in the area. The land-use type dominating the river basin consists of paddy fields, occupying almost three fourths of the landscape. However, it decreased from 74.93% to 71.13% of the landscape; that is, 301 hectares of paddy fields were lost be-

tween 1987 to 2003. The other significant land-use change was the rapid increase of built-up patches, dispersed across the paddy fields and increased by 576 hectares over the study period. Built-up land became the second largest land-use type in 2003, accounting for 8.88% of the Dongshan landscape.

3.2. Structural change of vegetative landscape

The paddy field contributes the primary land usage along the Dongshan River, occupying more than 70% of the total area of the landscape. The other vegetative land uses, classified as high-density and low-density vegetation, comprise only about 10% of the area. They include vegetation located in the Dongshan River Park and in two industrial areas, as well as the wind-breaking forest planted along the beach. As indicated in the previous section, all these three types of vegetative land use decreased in the class area and proportion of the landscape from 1987 to 2003. The data shown in Table 3 further delineates the structural change of the vegetative landscape.

Table 2. Change in Class Area (CA)[a] and Percentage of Landscape (PLAND)[b], 1987-2003

1987			**2003**		
Land-use type	CA (ha)	PLAND (%)	Land-use type	CA (ha)	PLAND (%)
Paddy fields	5943.61	74.93	Paddy fields	5642.31	71.13
High-density vegetation	314.53	3.97	High-density vegetation	307.09	3.87
Low-density vegetation	574.92	7.25	Low-density vegetation	440.05	5.55
Water	423.97	5.34	Water	408.19	5.15
Built-up land	128.19	1.62	Built-up land	704.22	8.88
Sandy beaches	547.28	6.90	Sandy beaches	135.41	1.71
Total landscape area	7932.5	100.00	Total landscape area	7637.27	100.00

[a] the total area of all patches for a particular land-use type
[b] the proportion of the landscape occupied by certain land-use type (class)
The above explanations were based on those of McGarigal, Cushman, Neel, and Ene (2002).

With regard to the paddy fields, while the values of the patch number, patch density, largest patch index, and mean patch area decreased slightly, there was a substantial increase in the patch edge. The total edge of the paddy fields increased by 15%, from 372,125 to 426,987.5 meters, and the edge density increased by 19%, from 46.91 to 55.91 (m/ha). In addition, there was also an increase in the landscape shape index, which provides a simple measure of class (land-use) aggregation (the increase of this value implies that the patch type has become more disaggregated). The LSI of the paddy fields increased from 12.63 to 14.91 (when normalized, from 0.0563 to 0.0647).

It can also be seen that there were different structural changes in high-density and low-density vegetation. All metric values, except for the largest patch index and the mean patch area, of the high-density vegetation decreased significantly. The patch number dropped drastically from 235 to 5 (with patch density decreasing from 2.9625 to 0.0655), although the class area lost only 7 hectares. In addition, the largest patch index and the mean patch area increased from 1.72 to 2.61 and from 1.34 to 61.42, respectively. All of these results suggest that high-density vegetation had become more aggregated by 2003. By contrast, the increase in patch number, edge and landscape shape index indicates that low-density vegetation underwent some degree of fragmentation during the study period.

Table 3. Structural change of vegetative landscape

Metrics	Paddy fields		High-density vegetation		Low-density vegetation	
	1987	2003	1987	2003	1987	2003
Class area (ha)	5943.61	5642.31	314.53	307.09	574.92	440.05
PLAND (%)	74.93	71.13	3.97	3.87	7.25	5.55
Number of patches[a]	20	19	235	5	13	19
Patch density (# / 100 ha)[b]	0.2521	0.2488	2.9625	0.0655	0.1639	0.2488
Largest patch index (%)[c]	72.73	72.13	1.72	2.61	2.70	1.12
Mean patch area[d]	297.18	296.96	1.34	61.42	44.22	23.16
Total edge (m)[e]	372,125.0	426,987.5	205,900.0	22,512.5	54,962.5	59,137.5
Edge density (m/ha)[f]	46.91	55.91	25.96	2.95	6.93	7.74
Landscape shape index[g]	12.63	14.91	29.12	4.96	6.35	8.40
Normalized LSI[h]	0.0563	0.0647	0.1998	0.0285	0.0280	0.0444

[a] the number of patches of the corresponding patch type
[b] the number of patches of the corresponding patch type divided by the total landscape area (converted to 100 hectares)
[c] the percentage of the total landscape area comprising the largest patch
[d] the total area of all patches of the corresponding land-use type, divided by the number of patches of the same type
[e] the sum of the lengths (m) of all edge segments of the corresponding patch type
[f] the sum of the lengths (m) of all edge segments of the corresponding patch type, divided by the total landscape area (hectare)
[g] the total length of edge (or perimeter) of the class, divided by the minimum length of the class edge (or perimeter) possible for a maximally aggregated class
[h] Normalized landscape shape index; the total length of edge (or perimeter) of the corresponding class minus the minimum length of class edge (or perimeter) possible for a maximally aggregated class, divided by the maximum minus the minimum length of class edge
The above explanations were based on the work of McGarigal, Cushman, Neel, and Ene (2002).

4. Discussion and Conclusion

4.1. Changes of the Agricultural Landscape

The change of rural landscape under the pressure of urban sprawl and economic development has been a key issue for agricultural land management in Taiwan. Council of Agriculture (2004a) conducted a project for the spatial allocation plan of agricultural land in Taiwan, in which the approach of Forman (1995) was used to analyze the changes of agricultural landscape on selected areas, including Yilan. It indicated that five major processes of landscape transformation were detected on the agricultural lands in Taiwan. They were perforation (formation of gaps), dissection (subdivision of patches by lines), shrinkage (reduction of patch size), fragmentation (breaking up of large patch into smaller parcels), and attrition (reduction of patch number). Focusing on a smaller scale, the results of this study shows that the agricultural land of the Dongshan River Basin have been gradually replaced by urban and tourism land uses.

According to the annual reports of Taiwan Tourism Bureau (2014), the park attracted an average of more than 1.3 million visitors each year until 2003, when the outbreak of severe acute respiratory syndrome (SARS) stroke down Taiwan's tourism, the visitors to the park decreased to 68.5 thousand. Despite the temporary depression of the park, the National Center for Traditional Arts built just across the park in 2002, soon became another hot tourist spot of Dongshan River Scenic Area. Now these two tourist spots are attracting more than 2 million visitors in total each year. From 1987 to 2003,

the major change in the river basin landscape was a rapid increase in the area of built-up patches, while the areas of all other land uses decreased. The main factor for the decrease in areas of high-density and low-density vegetation was the construction of two industrial parks. As for the paddy fields, although their overall structure was not significantly altered over the study period, 5% (301 hectares) of the paddy fields had been replaced by urban settlements, which included the river park, the bulky farm houses, and the center of traditional arts. The significant increase of small parcels (mainly farm houses), which dispersed across the paddy fields, changed the landscape with the process of perforation. These changes were the main contributors to the increasing patch edge and edge density of the paddy fields.

4.2. Ecological and Environmental Concerns

Rice paddy fields are a unique ecosystem, rich in biodiversity and able to sustain a diverse assemblage of plants and animals (Edrisinghe and Bambaradeniya, 2006). The environmental and ecological multi-functionality of paddy fields has received much attention. Natuhara (2013) indicates that landscape and temporal change are two major characteristics of the ecosystem of paddy field, and the linkage between paddy fields and the surrounding environment plays an important role in biodiversity. Paddy fields, including irrigation ponds and canal networks, have provided substituting habitats for a large variety of wetland species after the loss of natural floodplain by development (Washitani, 2007). Thus, the loss and change of paddy fields may cause certain degree of impact on the ecosystem services they provide. Viewing paddy fields in the Dongshan River Basin as unique man-made ecosystem, attention can be given to some environmental and ecological concerns.

First, according to Taiwan's Regulations for Building Farmhouses on Agricultural Land (Council of Agriculture, 2004b), up to 10% of each agricultural area is allowed to be used for the building of a farmhouse by the landowner. The rapid development of rural tourism in Dongshan River Basin has induced the increase and dispersion of farmhouses (mainly home stay facilities) within the paddy fields, and it may be regarded as a potential environmental hazard. As pointed out by Chang *et al*. (2006), paddy fields play an important role in flood control because they can gradually mitigate flood movement and provide flood detention. Therefore, the increase of built-up patches within paddy fields may cause adverse and cumulative effects on the flooding patterns in the basin. In addition, environmental pollutants associated with home stay facilities, like household wastewater, may also impose impacts on the surrounding paddy fields (Council of Agriculture, 2004a). The increase of the patch edge of paddy fields is another significant structural change to the vegetative landscape, which is caused by the perforation of built-up parcels. This process usually occurs with the shrinkage of agricultural land, and may eventually result in the fragmentation of the landscape (Council of Agriculture, 2004a). There has been much research focusing on the edge effects on birds. As pointed out by Joan *et al.* (2000), bird species richness is positively correlated to agricultural areas, and negatively correlated to urban areas. However, McGarigal *et al.* (2002) believe that edge effects should be viewed from an organism-centered perspective as edge effects influence organisms differently; that is, some species benefit from edges and some are adversely affected or unaffected.

4.3. Implication for further research

In Taiwan, previous research on changes in agricultural land use has focused on the spatial differences of landscape pattern changes in different areas, and the patterns of changes under urban influences, such as perforation, cutting, fragmentation, reduction, and loss (e.g., Lin and Lin, 1999; Tsai *et al*., 2003; Tsai and Huang, 2007; Wu, 2011). The ecological effects of different landscape-pattern change on the flora and fauna within paddy fields have not been well investigated and analyzed. Therefore, long-term investigation is suggested to assess the impact that the dispersion of built-up patches poses on bird species and biodiversity in paddy fields in Dongshan River Basin, and the future policies of local land-use management must take the ecological impact of these changes into account.

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MICROBIAL AND CHEMICAL POLLUTION OF WATER-WELLS RELATIVE TO SEWAGE EFFLUENTS IN OMAN

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Abstract. During the last four decades in Oman there has been a rapid increase in the population, construction of housing, heavy industry and also an increase in agriculture. This rapid growth shows no signs of abatement. This has led to an ever increase in water demand. Based on these facts, the existing methods of sewage water treatment and chlorination process is not effective in eradicating microbial contamination. In this study, the reuse of sewage effluent was one of the major causes of underground water pollution. Cracked septic tanks, cesspits, fertilizers and recycled treated sewage effluent (TSE) also added to underground water pollution. Excessive use of underground water due to water shortage led to salinization of the wells. A total of 276, 305 and 290 water-wells were sampled in 1995, 2000 and 2010 respectively for biological and physiochemical water contamination in Muscat, Oman. Relative to that, 300 samples of TSE were taken from four main sewage treatment plants (STPs). These samples were analyzed and compared with well-water samples. The analyses involved electrical conductivity, total dissolved solid (TDS), iron concentration, heavy metals, trihalomethanes (THMs), nitrate NO3 and microbial contamination. The dominant heavy metals in wells and TSE were Ni and Zn. In well-water, NO_3, TDS and microbial count were high. The above parameters declined significantly in 2010 because of heavy rain. Heavy metals, THMs and nitrates in some wells exceeded maximum permissible level even after the 2010 declined. Multiple antibiotic resistant bacteria (MARBs) were tested for 16 antibiotics and were found in both TSE and well-water. Resistance of *Escherichia coli* to antibiotics varied and multiple resistance was 2-8 antibiotics. Presence of THMs and MARBs in well-water is an indication of sewage contamination. A frequent analysis and stringent regulations must be implemented to avoid further environmental deterioration. Agencies need to begin implementing strict regulations to help in the prevention of the spread of pollution and disease.

Keywords: Well-water, Sewage effluents, Oman, Chemical pollutants, Antibiotic resistance

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1. Introduction

The water shortage and low rainfall is a major problem facing all aspects of life in Oman (Mahmoud *et al*., 2013, Al-Musharafi *et al*., 2014a). Due to rapid development which took place in the last 40 years, it is perfect model to study massive underground water pollution and environmental deterioration due to human activities (Al-Musharafi *et al*., 2014b). Rapid growth has resulted in an increase in water consumption, creating an imbalance between recycling and excessive use of underground water. The severity of the arid condition has forced the authorities to desalinate brackish and sea water and use the recycled water mainly for irrigation in areas such as public parks and greeneries. Most of the greeneries along the main highways are irrigated by treated sewage effluent (TSE). The government estimated that water usage and sewage produced is steadily increasing (Fig. 1). Similar situations occur in many countries in the world especially in the Arabian Peninsula (UNEP, 2013).

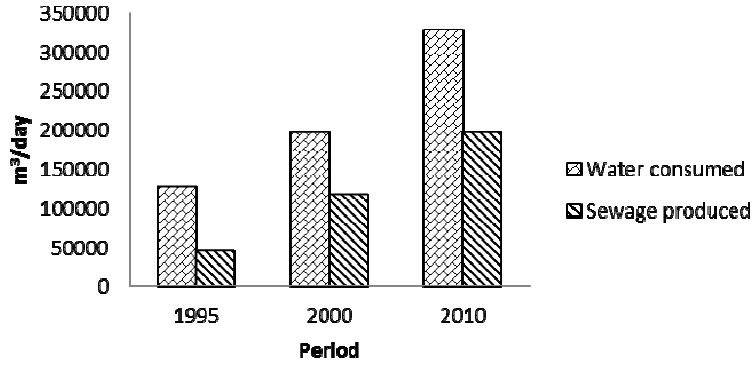


Figure 1. Water use and recycled treated sewage affluent. Estimated daily water demand in relation to sewage produced in Muscat during three periods

Due to excessive use of underground water for farming, water tables have fallen to lower levels, causing salinization which led to destruction of farmlands. As a result, many of the farms have been abandoned or converted to residential, commercial and industrial areas (UNEP 2013).

In order to solve the water-demand problem and at the same time meet the developmental needs, many countries in the arid zone have involved highly in costly desalination projects. The main municipal water source is desalinated sea water and the desalination program in Oman during the last 40 years has steadily increased to meet public demand. At the same time, recycling sewage water for irrigation of greeneries and agriculture has also increased. The common system for wastewater collection is septic tanks and cesspits. Recycling of sewage water for irrigation is becoming a common practice (Al-Bahry *et al*., 2000).

The use of sludge as fertilizer, septic tanks, cesspits and soakaways allow seepage of effluents into the soil contaminating underground water (Al-Bahry *et al*., 2000, Al-Bahry *et al*., 2014, Al-Musharafi 2014 b). Moreover, soil texture in many areas of Oman is porous, allowing easy penetration of effluents through the soil strata and consequently reaching the underground water (Al-Busaidi and Cookson, 2003). Both the recycled water and septic tanks may play a major role in contaminating underground water and wells. One of the reasons may be the irrigation of public greeneries which

depends mainly on usage of recycled water that is mainly TSE (Dewalle, and Scahff, 1980). Some contaminated effluents are dumped in waste lagoons contributing to underground water pollution (Al-Musharafi *et al*, 2014c). In addition, septic tanks and soakaways have risen substantially in housing, public buildings and industries. This may have resulted in a significant increase in the intrusion of sewage water from TSE, soakaways and cesspits through the soil and finally into water-wells (Al-Bahry *et al*., 2000). This facilitates an increase in microbes, chemicals and physical contaminants of underground water.

High concentration of heavy metals in drinking water has been responsible for a variety of chronic diseases, such as chronic anemia, liver cirrhosis, renal failure and a variety of cancers (Duan *et al*., 2011; Mishra *et al*., 2010).

Some chemical indicators can be used for detection of underground water pollution by sewage, such as nitrate (NO_3) and trihalomethanes (THMs). Nitrate in groundwater indicates that contamination may be the results of cracked septic tanks, cesspits, sewage-treatment plants (STP)s, or in some cases, fertilizers (Al-Bahry *et al*., 2000). Chlorination of drinking-water is used globally to disinfect microbial contamination. However, this process causes the formation of THM's which resulted in chlorine reaction with organic material in water-forming compounds such as chloroform, bromoform, bromodichloromethane and dibromochloromethane which may pose a health risk, include liver, colon, rectal, kidneys and bladder cancer. There is no unified international maximum limit of THMs in drinking-water (Government of Western Australia, 2009). Although THMs remain a public health concern, the International Agency for Research on Cancer and the World Health Organization reported there is insufficient evidence of health risks. However, *in vitro* studies on experimental animals revealed that THMs cause neurotoxicity, genotoxicity, acute toxicity, developmental toxicity, chronic toxicity, carcinogenicity and toxicity of the reproductive system (WHO, 2004). In Oman, stomach cancer is the most common reported, followed by non-Hodgkin lymphoma and leukemia (Al-Shereiqi 2008).

Water contamination is the most widespread health risk. Turbidity is an important factor for evaluation of water quality. Higher levels of total dissolved solids and turbidity in drinking water were found to be a major factor in causing gastrointestinal illnesses and infections (Egorov *et al*., 2003). *Escherichia coli* and other fecal microbes are commonly used as fecal contamination indicators. However, the absence of microbial indicator does not necessarily mean the absence of fecal pathogens (Van Lieverloo *et al*., 2007). Cases of hepatitis-B in Oman reached maximum levels in 1995 (Ministry of Health, Sultanate of Oman, 2008). Some nuisance microbes in water cause corrosion and changes in color, odor and taste, making water aesthetically unacceptable (Al-Bahry *et al*., 2011).

Heavy metal pollution in Oman caused by contaminated sewage effluents was reported by Al-Musharafi *et al*., (2012; 2013a; b, 2014a, b, c). Bacteria that are resistant to antibiotics are also resistant to heavy metals. Antimicrobial resistance mechanisms are linked to heavy metal tolerance mechanisms (Akinbowale *et al*., 2007; Bass *et al*., 1999). In another investigation, Hölzel *et al*., (2012), revealed that antibiotic resistant bacteria form pig manure have increased tolerance to heavy metals.

Bacteria in sewage sludge remain viable for several weeks. If such sludge is used as fertilizer, microbial contamination will increase in the environment consequently (Al-Bahry *et al*., 2014). Antibiotic-resistant bacteria were isolated from different environmental samples were used as bioindicators of contaminated effluents. Resis-

tant bacteria were isolated from treated sewage effluent, fish, marine turtles and fowls (Al-Bahry *et al*., 1999; 2006; 2007; 2009a; b; c; 2010; 2012). Antibiotic-resistant bacteria from treated sewage occasionally remained viable after chlorination (Al-Bahry *et al*., 2009a).

In this investigation, the data obtained from TSE and wells, relative to chemical, biological and physical contamination, were analyzed. The significant changes in vegetation were measured along with the changes of NO_3, using Remote Sensing (RS) and Geographical Information System (GIS) techniques.

This investigation is of value for conservation and environmental strategies to minimize pollution in Oman.

2. Materials and Methods

2.1. Selection of the study area and remote sensing analyses

The study area is located at longitudes of Eastern 2612000 and 2622000 and Northern 624000 and 608000 in Muscat, Oman. Landsat Thermatic MapperTM data from 1995-2010 was used to provide land cover information of Seeb, a suburb of Muscat. The method of Vanoverstreten and Trefois (1993) was used for Unsupervised classification maps. According to the method of Thomson (1992) Supervised classification was conducted. Normalized Difference Vegetation Index (NDVI) image was used to analyze vegetation changes. The area field of vegetation changes was estimated using Arc Map software version 10.5 in the study area. The feature classes of area fields were added in geodatabase automatically to estimate vegetation changes (Davenport and Nicholson 1993). False Color composite Landsat Image was used to identify urban areas, cities and towns (Williams 1983).

2.2. Well-water and TSE samples collection

A total of 276, 305 and 289 samples were collected from water wells in 1995, 2000 and 2010 respectfully. Three hundred sewage effluent samples from four main sewage-treatment plants (STPs) were also collected (100 samples per period). Sample collection and handling were analyzed following the standard methods (APHA/AWWA/WEF 1998; OS 52/1; OS 8/2006). Samples were collected aseptically every two weeks in sterile 500 mL glass and analyzed immediately after collection. Sodium thiosulphate pentahydrate ($Na_2S_2O_3{\cdot}5H_2O$, 100 mg/L; SIGMA, USA) was added to sample containers for water collection as a de-chlorinating agent to avoid bactericidal activity (WHO 1995). Oligodynamic activity of heavy metals was avoided by adding a chelating agent di-sodium salt of phenylenediaminetetracetic acid (EDTA, 372mg L^{-1}) and pH was adjusted to 6.5 (ISO 1994).

2.3. Bacteriological analysis of well-water and TSE

Glassware and sample bottles were washed with detergent, soaked in 0.1% free chlorine hypochlorite solution for 1 h and then rinsed several times with distilled water. Chlorine-free water was used for the final rinse. Sterilization of the glassware was conducted in a hot-air oven at 170 ^{o}C for 1 h.

Enumeration and isolation of heterotrophic bacteria was conducted following the method of Collins *et al*., 1995; British Standard BS 6068 1995. Enumeration of total coliforms and fecal coliforms, was conducted using membrane filters with a pore size of 0.45 ± 0.02 µm and a diameter of 47 mm (Millipore, Bedford, UK) according to Augoustinos *et al*., 1993; Aulicino and Orsini 1996; ASTM 1992.

2.4. Antibiotic susceptibility test

Luria Bertani broth was used to grow *E. coli* isolates to late logarithmic phase for 4–6 h at 37 ^{o}C. The isolates were inoculated on DST agar (Oxoid, UK) to make lawn cultures, using sterile swabs following the standards disk diffusion method of Bauer *et al*., (1966). The isolates were exposed to 16 antibiotics on DST agar and incubated at 37 ^{o}C for 24 h (National Committee for Clinical Laboratory Standards, NCCLS, 1997). Measurements of Inhibition zones were done after incubation for 18–24 h at 37 ^{o}C according to the international standards of disk diffusion method. *E. coli* (ATCC 25922) was used as a control. The antibiotics used were: Amikacin (Ak) 30 µg, Ampicillin (Amp) 10 µg, Carbenicillin (Cn) 100 µg, Cephotaxin (Ctx) 30 µg, Chloramphenicol (C) 30 µg, Ciproflaxacin (Cip) 30 µg, Gentamicin (Gm) 10 µg, Kanamycin (K) 30 µg, Minocycline (Min) 30 µg, Nalidixic acid (Na) 30 µg, Neomycin (N) 30µg, Sulfamethoxazole (Smx) 30 µg, Streptomycin (S) 10 µg, Tetracycline (Te) 30 µg, Trimethoprim (Tmp) 5 µg, and Tobramycin (Tob) 10 µg.

2.5. Physicochemical analysis of sewage and water

Free chlorine in water samples was measured using a chlorine test kit (CHEMetrics, Inc., USA). A bluish-violet color indicates positive results for free chlorine. Chlorine concentration was determined by the color produced compared with the provided standards of the kit.

A conductivity meter was used to measure water salinity on site. Pre-calibration of the conductivity meter was done according to the manufacturer's instructions.

Ion chromatography was used to measure the nitrate concentration. 1 mL of water sample was added to a volumetric flask containing 25 mL of double de-ionized water and then injected in the ion chromatography apparatus (Long & McClenny 2006).

Detection of chloro-compounds was analyzed according to the methods of Wolska *et al*., 1998. Physicochemical analysis of samples was carried out using distilled and deionized water (British Standard BS 6068 1995). The glassware was cleaned with detergent and treated with HNO_3 (0.1 N) then rinsed thoroughly with deionized water. Free and total chlorine concentrations were conducted using the HACH free and total chlorine test kit (HACH Company, USA). The detection range was from 0.0 to 0.7 mg L^{-1} for the free chlorine and from 0.0 to 3.5 mg L^{-1} for the total chlorine. Lovibond drinking-water test kit (Lovibond, USA) was used to examine the color, then measured in Hazen units with a detection range of 5 to 70 units.

The water pH was measured during sampling using a pH meter (Orion, USA).

TDS, EC, and salinity measurements were conducted using field-equipped electrodes (Orion, USA).

Water and sewage samples were analyzed for heavy-metals; Al, As, B, Cd, Co, Cr, Cu, Fe, Hg, Mn, Mo, Ni, Pb, V and Zn using Inductively Coupled Plasma Optical Emission Spectrometer (ICP-OES) type Perkin Elmer 3300 DV ICP (USA).

3. Results

The data were based on the examination of 276, 305 and 290 wells in 1995, 2000 and 2010 respectively. A total of 300 TSE samples were collected from four main STPs and were compared with the well-water samples.

The meteorological records show that the annual rainfall between 1995-2010 was very low with the exception of 2004, 2006 and 2007 with an unusual high rainfall. In 2007 the cyclone Guno produced a substantial rainfall within 48-hours, causing serious damage and floods. In addition, an extraordinary rainfall was recorded in 2004 and 2006 (Fig 2).

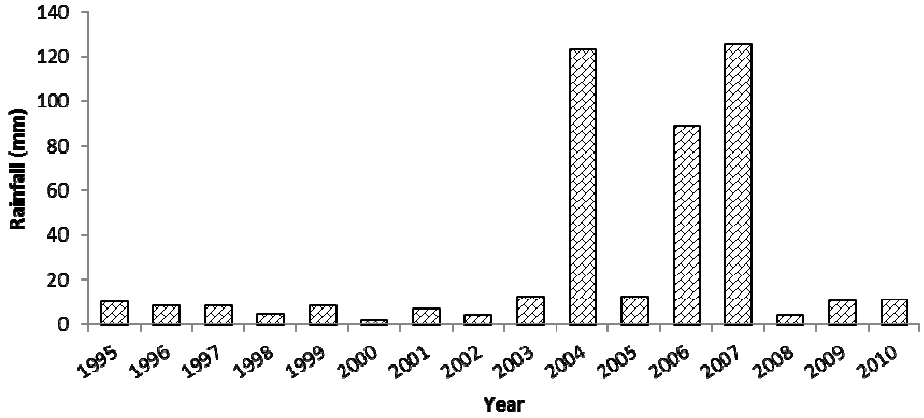


Figure 2. Annual rainfall 1995-2010. The annual rainfall in Oman is minimal except for the year 2004, 2007 and 2007

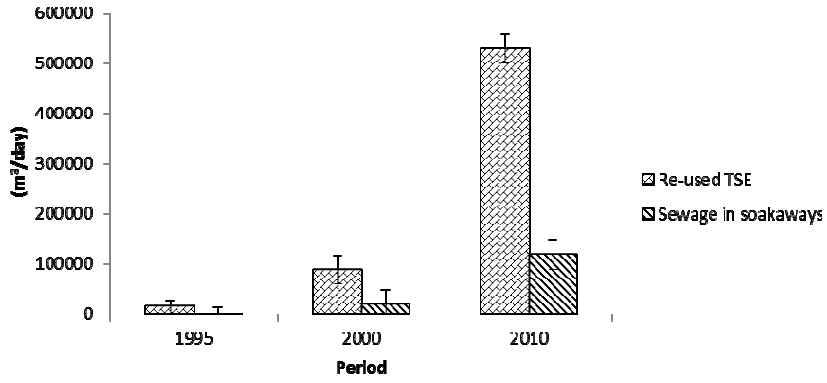


Figure 3. Sewage reuse and sewage in soakaways in Muscat during three periods

The estimated average of both treated sewage effluent and untreated sewage in soakaways significantly increased ($P < 0.05$) during 1995-2010 (Fig 3). The NDVI of Landsat TM satellite image showed vegetation changes in the study area with the colors green, yellow, and red represent vegetation distribution in 1995, 2000 and 2010 respectively (Fig 4). Image analysis revealed that there was a steady decrease and deterioration in vegetation due to depletion and drastic decrease of well-water levels. Most of the damaged areas of vegetation were replaced by housing, public buildings and industries (Fig 5). Based on NDVI of Landsat TM satellite image of vegetation changes in 1995 was 9025 m^2 but increased to 12160 m^2 in 2000. However, the vegetation decreased

drastically in 2010 to 4650 m^2. Water salinity as indicated by EC values was the highest during 1995 and 2000, However, EC dropped significantly ($P < 0.01$) in 2010 (Fig 6).

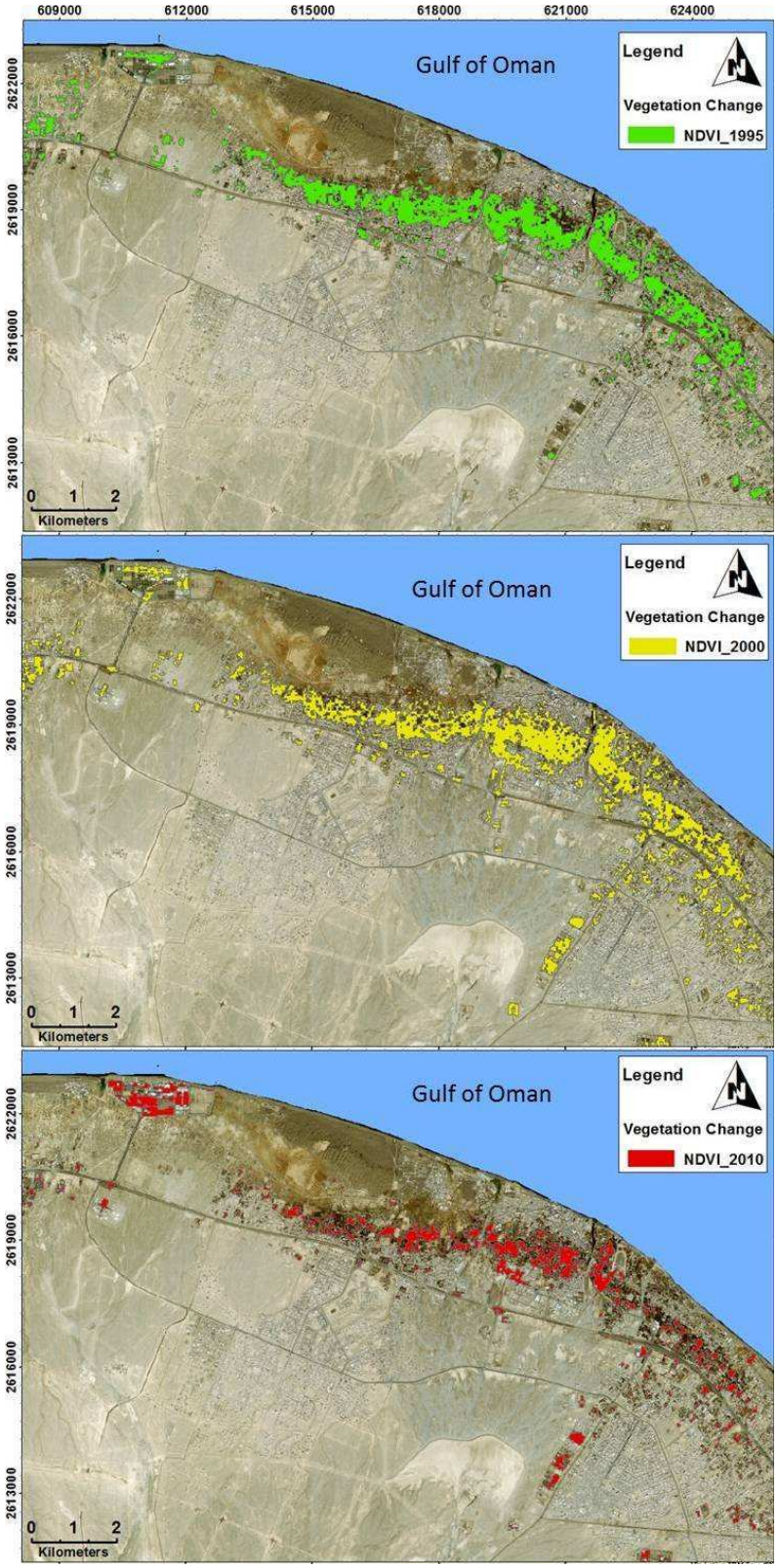


Figure 4. NDVI of Landsat TM satellite image of vegetation changes in Seeb-Muscat. Data acquisition for 1995, 2000 and 2010. Image IKONOS 1m resolution

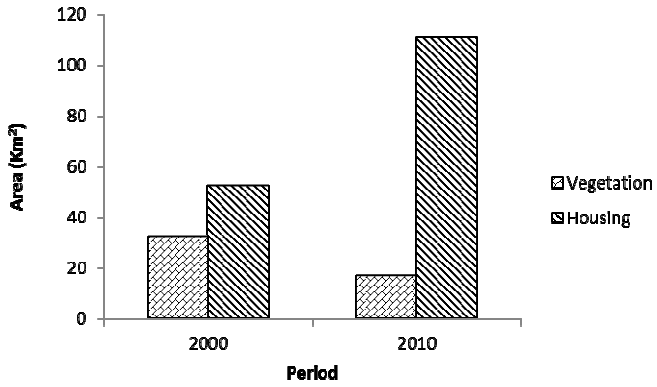


Figure 5. Changes in vegetation in relation to housing development, based on remote sensing image data acquisition in 2000 and 2010. See also Fig 4.

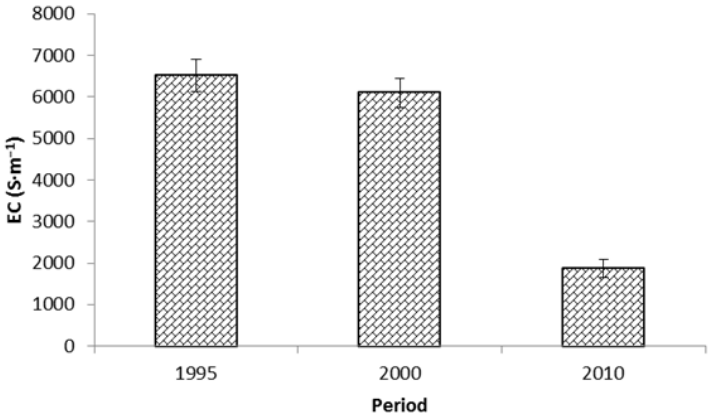


Figure 6. Electrical conductivity of well-water (SE±) during three periods.

The highest ion concentration of both well-water and TSE water was Na and Cl. Also the concentration of SO_4, was similarly high in wells in 2010. However, Mg and Ca were at low levels in both well-water and TSE (Fig 7). The dominant heavy metals in both well-water and TSE were Ni and Zn followed by Cr. These elements were significantly higher in TSE than in wells ($P < 0.05$). The rest of heavy-metals were at lower levels (Fig 8).

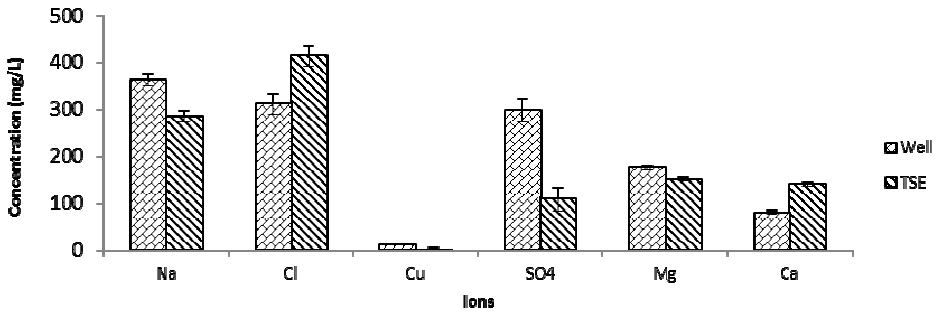


Figure 7. Ion concentration (SE±) in wells and TSE (2010).

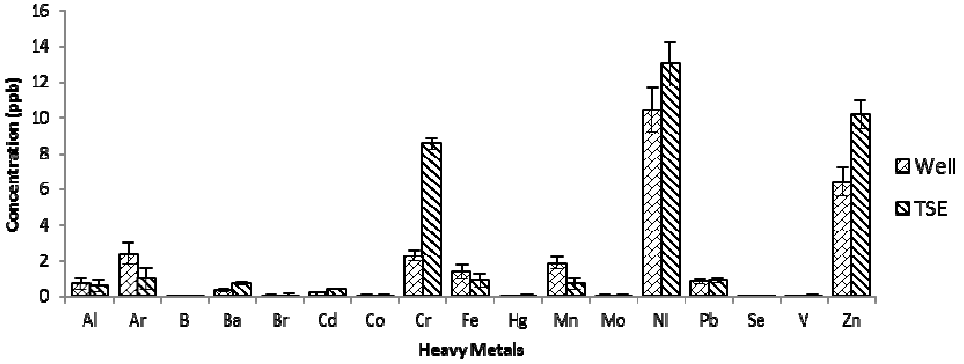


Figure 8. Heavy metals concentration (SE±) in wells and TSE (2010).

Based on Omani standards for TSE (OS 52/1) and drinking water (OS 8/2006) few of the wells exceeded the minimum permissible levels (MPL) for heavy metals analyses in 2010, Overall they were higher in TSE than well-water (Table 1).

Trihalomethanes concentration, which included bromoform, chloroform, bromodichloromethane and chlorodibromomethane in wells (1995 to 2010) and in TSE (2010), showed variation throughout the study period (Fig 9). There was a significant decrease in the four trihalomenthanes in 2010. However, chlorodibromomethane was highly significant ($P < 0.01$) in 1995 and 2000 over the others during the same periods. In TSE, chloroform concentration was the highest and there was no significant difference between the four compounds ($P < 0.01$). The percentage of wells with THMs above the MPL varied, (Fig. 9 and 10). Most of the wells that exceeded the MPL were in 2000 and the lowest in 2010.

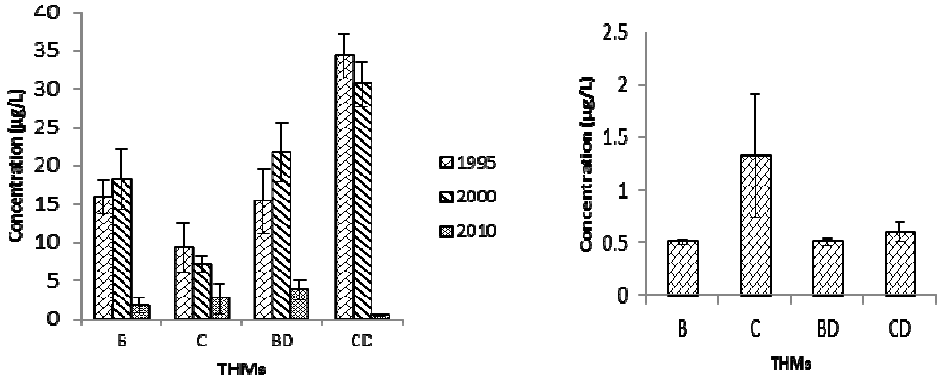
Also, the maximum nitrate concentrations in wells during the three periods were in 1995 and 2000 (Fig 11a). Based on the data presented in Fig 11a the percentages of wells with high nitrate concentrations exceeded the MPL according to the Omani Standard Drinking-Water (Fig 11b). The lowest percentage of wells with nitrate was in 2010. Relative to Fig 11a, nitrate concentration in wells, using satellite image distribution in the study area in 1995, 2000 and 2010, varied significantly (Fig 12). Red dots represent the highest concentrations in wells.

Similarly, the highest values for microbial count (cfu/ml) of coliforms, enterococci and *E. coli*, were recorded in 1995 and 2000. The lowest counts were in 2010. *E. coli* remained low throughout the three periods (Fig 14). In TSE the coliform and enterococci data in 2010 were not significantly different. However, colony forming units for *E. coli* was significantly lower than the other two (Fig 15). The *E. coli* isolates varied in their antibiotic resistance. Out of the sixteen antibiotics, most of the strains were resistant to more than one antibiotic (Fig 16). Isolates from TSE were more resistant to antibiotics than the isolates from the wells. In general, the dominant resistance to antibiotics from wells and TSE isolates was to ampicillin, followed by tetracycline, minocycline, and streptomycin and sulphamethoxazole. None of the well-isolates were resistant to amikacin, chloramphenicol, neomycin and nalidixic acid.

There was insignificant difference in TDS values in 1995 and 2000. However, TDS decreased significantly in all examined wells in 2010 (Fig 13).

Table 1. Percentages of TSE and wells with heavy metal concentrations in 2010 relative to minimum permissible levels (MPL) according to Omani Standards for TSE (OS 52/1) and for drinking water (8/2006).

Element	Minimum Permissible Levels (MPL)		% Exceeded MPL	
	TSE (mg L^{-1}) OS 52/1	Drinking water (mg L^{-1}) OS 8/2006	TSE	Drinking water (wells)
Al	5	0.1	1.8	0.4
As	0.1	0.01	0.2	0.5
B	1	0.5	0.3	0.04
Ba	2	0.7	0.1	0
Br	0.01	0.01	0	0
Cd	0.01	0.003	0.7	0.9
Cr	0.05	0.05	0.6	0.5
Co	0.05	0.05	0.2	0.1
Fe	5	1	0	0.07
Hg	0.001	0.001	0.4	0.3
Mn	0.5	0.1	0	0.07
Mo	0.05	0.07	0	0
Ni	0.1	0.02	8.3	4.4
Pb	0.2	0.01	1.5	1.1
Se	0.02	0.01	0	0
V	0.01	0.01	4.1	3.9
Zn	5	3	7.2	4.9



a b

Figure 9. Trihalomethanes (B=bromoform, C=chloroform, BD= bromodichloromethane, CD= chlorodi-bromomethane) concentrations (SE±) a: in wells during three periods (1995, 2000 and 2010); b: in TSE (2010).

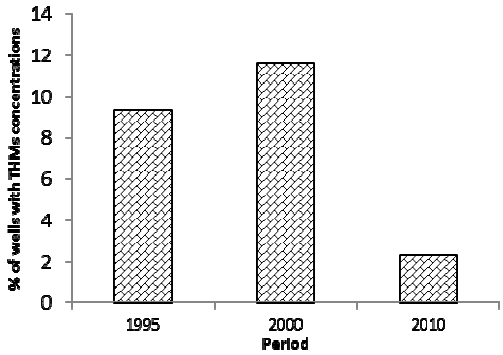
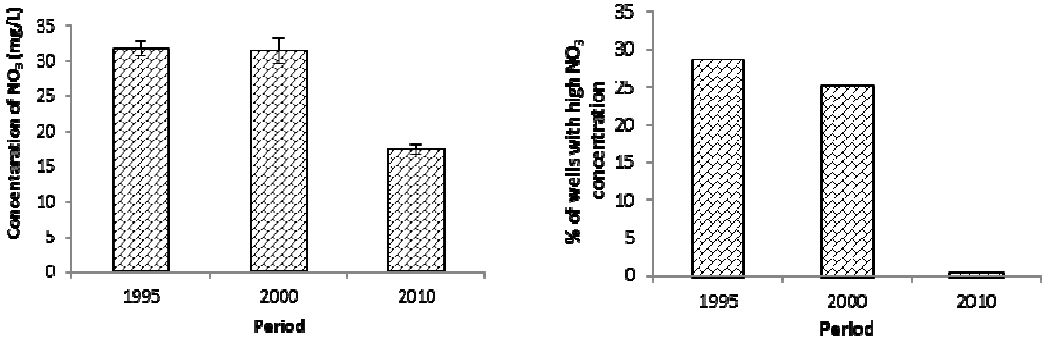


Figure 10. Percentage of wells with THMs above the allowed minimum permissible levels (MPL).



a b

Figure 11. Nitrate concentration (SE±) in well-water during three periods, **a** = nitrate concentration, **b** = percentage of wells with nitrate concentration exceeding the maximum permissible level (MPL) of the Omani-Standard Drinking-Water (50 mg L^{-1}).

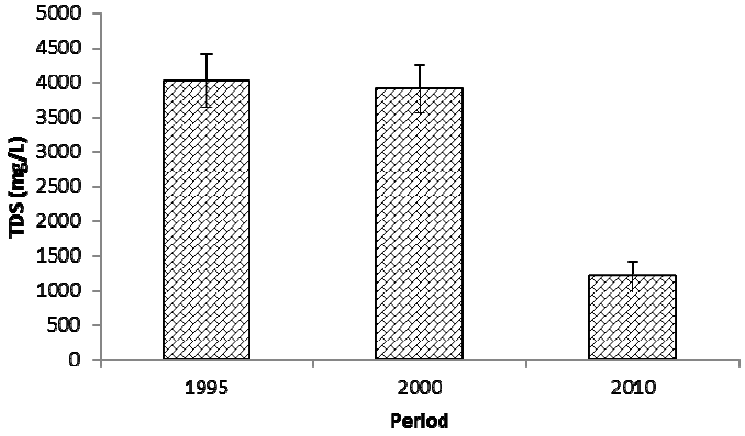


Figure 13. Total dissolved solids (TDS) (SE±) in well-water during three periods.

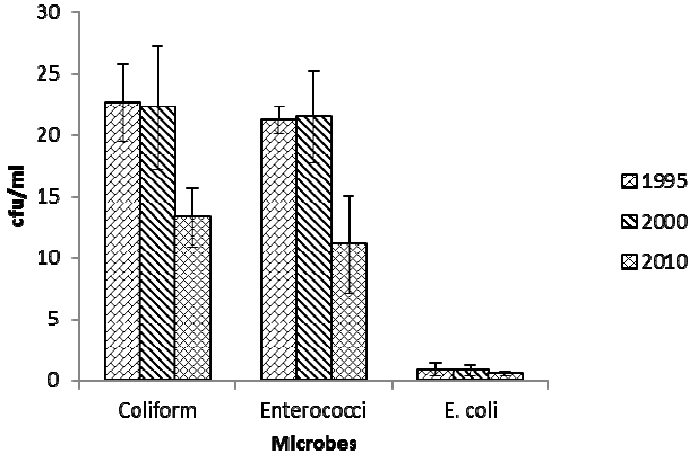


Figure 14. Microbial count (cfu/ml) (SE±) in well-water during the three periods.

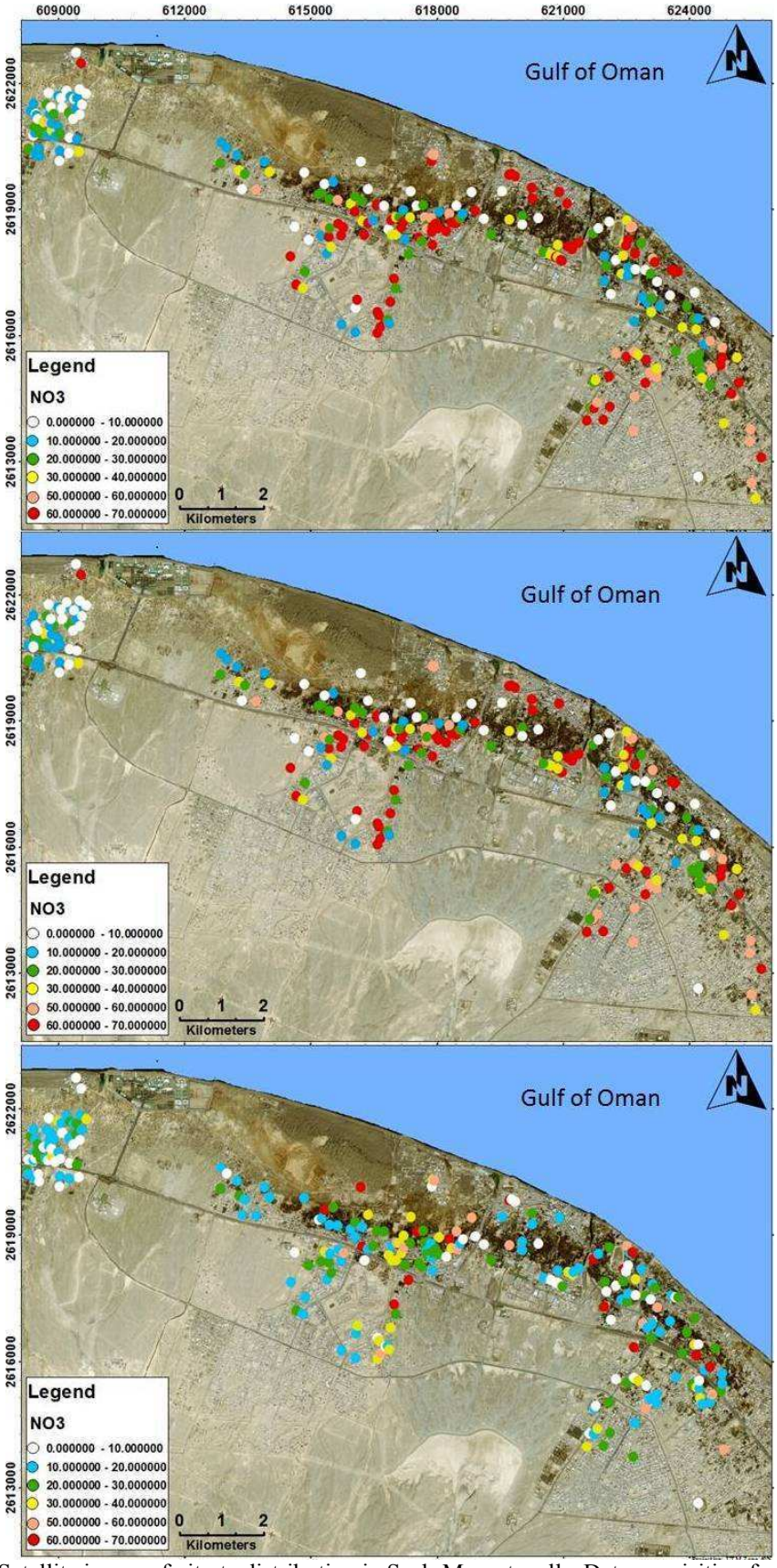


Figure 12. Satellite image of nitrate distribution in Seeb-Muscat wells. Data acquisition for 1995, 2000 and 2010. Image IKONOS 1m resolution.

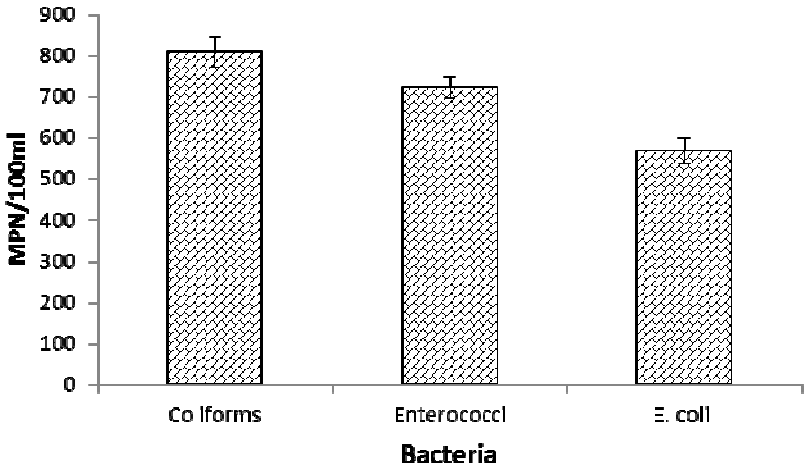


Figure 15. Microbial count (cfu/ml) (SE±) in TSE in 2010.

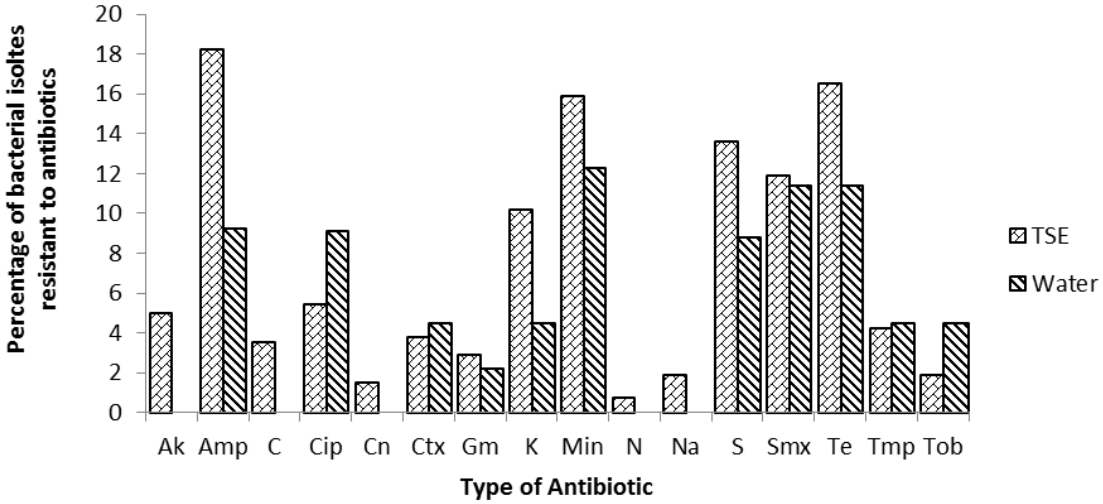


Figure 16. Antibiotic-resistant *Escherichia coli* in TSE and well-water.

4. Discussion

A survey of chemical, biological and physical factors which had an environmental impact in the Seeb area was investigated during three periods. During these periods there was a gradual deterioration in environmental and ecological conditions which threatened Seeb.

Approximately 200 sewage treatment plants are located in Muscat and the area in which this study was conducted. However, a small percentage of the populated area is connected to the sewage system, with most using septic systems, holding tanks, and cesspits. Due to poor construction, untrained work force, along with infrequent inspections, the older systems are breaking down and inadequate, thus allowing wastewater to discharge into the surrounding soil which is also porous (MEMWR 1998). A large amount of wastewater is discharged directly into the soil. Therefore, holding-tanks should be installed in areas where sandy soil, high water table, and dense housing are

characteristic. Various public health and environmental pollution will take place if this is not done, ranging from food poisoning to disease causing pollutants such as cancer. To avoid contaminated sewage intrusion into the environment, the authorities have taken a major step in planning to construct one of the largest membrane bioreactor (MBR) in the world, serving 90% of the Muscat residents. The project is expected to be finalized in 2017, connecting more than 18 thousand houses and public institutions with 330 km of pipeline of which 70km of pipeline will be used to distribute treated effluents for agriculture and public use (Water technology 2014).

Due to severe shortage of rainfall in Oman, TSE is used for irrigation or discharged to soakaways, wadis, boreholes and some to the sea. In addition, the underground water is polluted by infiltration of untreated sewage from cracked holding tanks, septic tanks, and cesspits.

Two types of STPs are operated either by government or private agencies, most of which are in Muscat. According to Government regulations, STP inspection in Muscat is supposed to be conducted monthly. However, STPs inspection is irregular. These regulations need to be vigorously enforced (MEMWR 1998). Sewage treatment plants in Muscat have been privatized. HAYA-Water is a new establishment for wastewater services which is planning to use MBR technology. It is expected to produce cleaner sewage treated effluent with effective inspection systems.

In this study, based on microbiological and physicochemical data, it is evident that well-water is contaminated by sewage effluents. Several factors influenced the environmental and ecological conditions which resulted in major deterioration of well-water quality in affected farmlands, loss of natural vegetation, and may have an impact on public health in the region. All these factors directly or indirectly, could be responsible for economic loss (Raina and Sangar 2002, Olmstead 2010, WHO 2001). For example, thousands are spent for treatment of diseases which could possibly be prevented (WHO 2001). Overuse of underground water was probably one of the major factors that led to high salinity of most wells and caused significant vegetation changes in the area, which then led to abandonment of most farms. This was followed by extensive urbanization of farmlands which was another environmental and ecological factor that led to substantial underground water pollution. A similar trend of water pollution was also reported by Kodarkar (2004) in Hyderabad, India.

Due to having little rainfall, and with extensive use of groundwater, the salinity and chemical pollution rendered the farmland unfit for farming and led to its abandonment and being used for urbanization. The urbanization then led to a significant increase in construction of septic tanks, holding tanks and cesspits. Deterioration in ecological conditions was also related to dramatic population increase. This major increase in industry and population growth has consequently led to an ever increasing demand for water.

High concentrations of THMs were detected in samples near the wells close to the irrigated greeneries and public parks. This suggests that THMs are good indicators for TSE infiltration into the ground water. According to the Omani standards, OS 52/1 and OS 8/2006, several wells were found to exceed MPL which is in agreement with standards of some major health organizations (WHO 1982; NSF International 2003; The soil profile 2006; Mahadev *et al*., 2010). These standards must be followed to avoid further THMs pollution, even though there is no unified international maximum limit of THMs in drinking-water (Government of Western Australia 2009). The WHO (1982), NSF International (2003) and The Soil Profile (2006) standards could be used as basis

for THM maximum limit in water to avoid health risks of different types of toxicities leading to physiological toxicity of organ systems and cancers (WHO 2004).

TDS, NO_3, and fecal coliforms are the main parameters chosen to determine the quality of the treated wastewater. High levels of nitrate were found in many samples. Sewage from nearby septic and holding-tank leakage may be the main factor contributing to nitrate contamination. Nitrate concentration was recorded at maximum levels in 1995-2000. More than 25% of the wells exceeded the permissible levels according to the Omani-Standards Drinking-Water 8/2006 (OS 8/2006). Nitrate contamination of underground water may also occur from fertilizers. Nitrate has also been used as an indicator of microbial activity and growth. Al-Bahry *et al*., (2009a) reported that nitrate concentrations are related positively to microbial growth in TSE distribution and irrigation lines. They reported that viable bacteria and nitrate concentrations in the distribution lines increased significantly farther from the STP storage reservoir.

TDS is considered an important factor for assessing water quality. TDS in well-water during the three periods reached maximum values during 1995-2000 but decreased significantly in 2010. High TDS levels probably originated from contaminated effluents with organic and inorganic contents in water such as industrial wastewater and agricultural run-off, and possibly form natural environments. Its levels in a natural environment may vary, depending on geological regions. Higher TDS levels in drinking water may be related to cancer and cardiovascular problems, such as coronary and arteriosclerotic heart disease, as well as gallstones and inflammation of the gallbladder. Higher concentrations lead to corrosion and scaling of water distribution lines and house hold appliances (WHO 2003). Higher turbidity level is an indication of high microbial contents in water. Turbidity protects microorganisms and stimulates microbial regrowth even after disinfection (Al-Bahry *et al*., 2009a, 2011, WHO 1997,). Egorov *et al*., (2003) reported that high turbidity concentration in drinking-water was a major factor for gastrointestinal illnesses.

Microbial counts of coliforms, enterococci and *E. coli* were much higher in TSE than in well-water during the three periods. Many of the wells were contaminated with *E. coli*. Detection of *E. coli* in water also indicates the presence of pathogenic protozoans, bacteria and viruses. Due to these conditions, microbial diseases such as cholera, typhoid and hepatitis are serious illnesses associated with water contamination (Sonnenwirth and Jarett 1988). According to Calderon & Mood (1998, 1991) potential pathogens occasionally exist in large numbers in water; however, when they are in small numbers they are unable to cause infection. There was a significant increase of chemical and microbial food poisoning in recent years in Oman (Community Health Disease Surveillance Newsletter 1998, Ministry of Health, Oman 2005) while the endemic viral hepatitis cases in Oman reported in the same period was fluctuating (Ministry of Health, Oman 2005). Probably, the infection is due to fecal contamination of well-water (Sonnenwirth and Jarett 1988).

In this study, the highest heavy metal concentration is probably related to sewage infiltration. Also, porous soil conditions may contribute to the infiltration of pollutants in well-water. The frequent heavy metals found in both well-water and TSE were Ni, Zn, and Cr. Many of the detected heavy metals in this study are commonly used in industries (Iqbal and Gupta 2009). In addition, the composition of ground water is affected by the lithology of rocks and quantity of infiltrating rainfall. Biological and human factors can alter water composition (Salem *et al*., 2000). Skeat (1969) reported that heavy metal impurities penetrate the soil to reach underground water through sewage

and industrial effluents. A number of international organizations recommended safe levels of heavy-metals in drinking water (Adefemi and Awokunmi 2010; Krasniqi *et al*., 2010; Lungu *et al.,* 2010; NSF International 2003; OS 8/2006; The soil profile 2006). However, with the exception of Ba, Br, Mo and Se, other heavy-metals in wells surpassed the safety levels which made drinking-water unsafe. Heavy metals and its distribution in wells in the study area also depend on the nature of soil and underground rocks. However, their level from natural sources is usually low (EPA 2012). The source of heavy metal in the well which acceded MPL is probably from the surrounding industries or the overuse of underground water in arid regions, such as Oman (Al-Musharafi *et al*., 2012, 2014a). With this in mind, there is a gradual accumulation of heavy metals in well-water which may lead, in time, to higher percentages of contaminated wells. Due to the availability of fresh water provided from the governmental sources in recent years, most of the wells are not being used for drinking purposes.

Many of *E. coli* isolates from both well-water and TSE were multiple-resistant to antibiotics and their resistance varied to the 16 antibiotics. The isolates were highly resistant to ampicillin, minocycline, streptomycin and tetracycline. Al-Bahry *et al*., (2009a) reported that the majority of the isolates from TSE distribution lines were multiple-resistant to several antibiotics. The isolates resisted the chlorination process and remained viable in TSE and distribution lines. They reported that the isolates exhibited maximum resistance to ampicillin followed by sulphamethoxazole, carbenicillin, streptomycine, and minocycline. They also observed that viability of MARB TSE used for irrigation may have serious complications for public health and wildlife where inhabitants can be infected by MARBs. Al-Bahry *et al*., (2009b; c; 2010; 2012) used multiple antibiotic resistant bacteria for biomonitoring of environment and bioindicators of pollutions caused by contaminated effluents. The overuse of antibiotics for treatment of diseases, prophylaxis and growth promotion in Oman caused the emergence of multiple antibiotic resistant microbes and led to contamination of soil and aquatic environments via sewage and agricultural runoff (Al-Bahry 2009b, c, 2010, 2012, Mahmoud *et al*., 2013).

Globally, microbial infections were the most common diseases before the World War II and infections became insignificant due to antibiotic treatment. However, emergence of antibiotic resistant strains became very common and new generations of antibiotics are continuously being introduced. WHO (2014) published comprehensive data collected from 114 countries which reveals the major threat of MARBs and that antibiotics are no longer effective in treatment of infections. Some common infections which were curable are now becoming untreatable (WHO 2014).

Based on the present data, the highest concentrations of salinity and all contaminants associated with leakage of effluent from cesspits, septic and holding-tanks were recorded between 1995 and 2000. Salinity and contaminants concentrations dropped significantly in 2010. This is probably attributed to a significant amount of rainfall in 2004, 2006, and during the cyclone Guno in 2007. The heavy rainfall during these years has significantly diluted contaminants of underground and well-water.

The Omani population in 1995, 2000, and 2010 was 2.155, 2.193, and 2.8 million respectively, excluding expatriates. It is estimated that Omani population will increase to approximately 5 million in 2030 (The Demographic Profile of Oman, 2014). Based on population growth and the data presented above, there is a serious health problem due to leakage of wastewater from the cesspits, septic, and holding-tanks to well-water. This problem will escalate with dramatic increase in population which leads to an

increase in water usage and expanding urbanization using septic and holding-tanks. These conditions will result in a steady increase of sewage, containing health-threatening contaminants such as pathogenic microbes, chemicals and changes in the physical characteristic of ground water. The most frequent limiting factors for potable use of water is total salinity estimated as (TDS), or more as electrical conductivity (EC). Incidence of cancer on the rise may be related to the high concentration of nitrates and heavy metals. Also, water hardness is one of the common causes of kidney stones (Bellizzi *et al*., 1999).

The regional governments have undertaken research to reduce the cost of desalination and enacted environmental legislation to minimize the environmental impact of TSE (MEMWR 1998). These regulations affect wastewater reuse and discharge of effluents, and the construction of septic tanks and holding tanks. It is imperative that the reused quantity of TSE in irrigation should be in conformity with the physicochemical and microbiological standards set by the Government authorities (WHO 2005). With the establishment of new institutes dedicated for the management of STPs and the treatment of sewage effluents, it is imperative that the physicochemical and microbiological standards will be followed.

If this trend continues without stringent environmental regulations and scientific investigations, it will lead to gradual deterioration in ecological and environmental conditions. During the last few years, there was a steady decrease in water resources mainly due to the lack of rainfall. In the study area alone, there has been a substantial increase in population and greeneries up to six-fold between 1980 and 1990. Only 45% of sewage effluent was treated, with the remaining going to sea and soakaways (MEMWR 1997). With the steady increase in population, the demand for fresh-water usage has increased significantly from 12000 m^3 to 34000 m^3 daily. During the last forty years, rapid development in all aspects, including population increase, social, industrial and agricultural sectors resulted in higher demand for water consumption.

5. Conclusions

In conclusion, the data presented in this study are alarming. In this study, MARBs were used as biological indicators of sewage effluent pollution. In all surveyed pollutants, MARBs and heavy metals are the main public health concerns. Heavy rainfall in 2010 diluted the pollutants. The necessity of reusing recycle water in this region caused accumulation of several chemical pollutants. Stringent governmental regulations and institutional monitoring are urgently needed.

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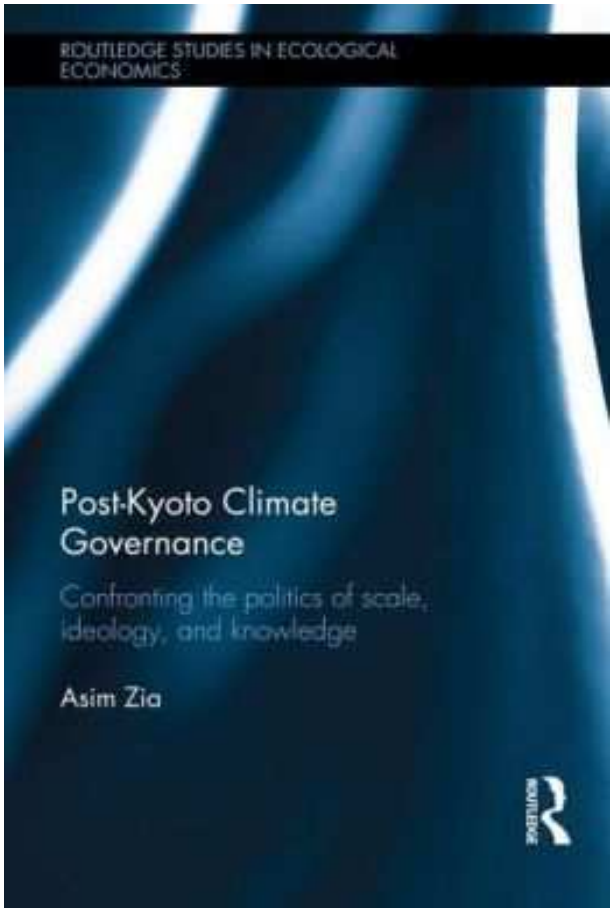
POST-KYOTO CLIMATE GOVERNANCE – CONFRONTING THE POLITICS OF SCALE, IDEOLOGY AND KNOWLEDGE (ASIM ZIA: ROUTLEDGE, LONDON AND NEW YORK, 2013, ISBN 978-0-415-60125-2)

Sorin Cheval, PhD[1]



Nowadays, climate change is probably one of the topics that can attract the genuine interest of human society. Individuals either agree or disagree with the man-made influence on the present and future climate, but they can hardly ignore facts like glacier melting or changes in atmospheric chemistry.

Unprecedented investments in climate related science, policy, and actions have been taken by local communities, countries, and international associations. By its end in

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2012, the Kyoto Protocol concentrated the nations' efforts for controlling the emissions of the main anthropogenic greenhouse gases according to criteria balanced between their wealth and capacity to make reductions. The debate over the success of Kyoto is far from ending, but the discussions are is probably less important than the follow-up.

Dr. Asim Zia's *Post-Kyoto Climate Governance* scrutinizes the accumulation of knowledge, ideas and facts regarding the near future; thus, it is both a theoretical inter-disciplinary and multidisciplinary reflective book, and a valuable inspiration source for applies development. The alternatives of the post-Kyoto climate governance are thoroughly presented, including the basic ideology, spatial and temporal scales, transition issues, possible conflicts and agreements.

No matter the reader's professional skills and background, the book would captivate the attention of those interested in a global and comprehensive perspective on risk perceptions, marketing, and adaption to the climate change possible impacts in the post-Kyoto era.

Dr. Asim Zia pledges for governing the environmental complexity through a coupled human and natural systemic approach which takes into account in a flexible way various scales and issues, aiming for "*a more legitimate and accountable post-Kyoto climate governance regime in the medium and long run*".

Students, climate experts, stakeholders and decision makers have the chance to go through a captivating work which would equally challenge the global warming supporters and climate skeptics to argue their points of view.

AUTHOR GUIDELINES

1. IJSEE: Aims and Scope

The **International Academic Forum** (IAFOR) is a mission driven organization dedicated to providing and promoting meaningful dialogue irrespective of international borders founded in 2009 by a group of concerned Asian, European and North American academics and business professionals.

IAFOR Journal of Sustainability, Energy and the Environment (IJSEE) reflects the IAFOR Asian Conference on Sustainability, Energy and the Environment, but articles from other sources can also be accepted. IJSEE is published online and made freely available. Neither editors nor authors are remunerated.

IJSEE publishes original papers, theoretical or presenting the results of research (written as short notes or full research papers), opinion articles, conference reports, extensive literature reviews and book reviews in the three areas of interest, environmental sciences, sustainability and energy, pertaining to one or more of the following subjects: (1) agroecology, (2) aquatic and marine ecology, (3) biogeochemistry, (4) biogeography, (5) community ecology, (6) conservation biology, (7) ecological anthropology, (8) ecological design, (9) ecological economics, (10) ecological engineering, (11) ecological succession, (12) ecophysiology, (13) ecotoxicology, (14) energy, (15) environmental psychology, (16) environmetrics/quantitative ecology, (17) evolutionary ecology, (18) forest ecology, (19) human ecology, (20) hydrobiology, (21) industrial ecology, (22) microbial ecology, (23) population ecology, (24) restoration ecology, (25) social ecology, (26) soil ecology, (27) sustainability, (28) systems ecology, (29) theoretical ecology, (30) urban ecology. The journal is dedicated to publishing only the best papers on each subject fitted with its scope.

The peer review process consists of the evaluation of submissions by two international reviewers and a member of the Editorial Board. The member of the Editorial Board can decide whether the article is not publishable (if its contents does not fit with the Journal or it does not meet the minimal standards), or send it to the reviewers. In the second case, the article is reviewed by a reviewer proposed by the author (must be from a different country than the author) and one assigned by the journal. If their opinions do not coincide, the member of the Editorial Board performs his own review and takes the final decision. No manuscript will be accepted or published without peer review.

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(b) Reference list

(i) Books: Surname, Initial. (Year), *Title*, Publisher, Publishing Company's Nearest Headquarters (e.g. London): Douglas, M. & Watson, C. (1984), *Networking*, Macmillan, London.

(ii) Chapter in edited books: North, D. (1980), 'Energy use at home', in *Energy Conservation*, eds S. Scott & N. Peel, Academic Press, London.

(iii) Journal articles: Surname, Initial. (Year), *Title of Paper*, Journal, volume and number, page numbers. The details about the volume etc. can be given fully (e.g. vol. **1**, no. **3**, pp. 10-18.) or abbreviated to give just numbers (e.g. **1 (3)**, 10-18.): Gibberd, R., Snow, P.T., Rice, P.G. & Patel, N.B. (1991), 'Nuclear power at what price?' *The Bulletin,* **113** (4), 51-5. If the number (issue) is unknown, the reference list should specify at least the volume of the journal.

(iv) Government publications: Department of Energy, (1980), *Projections of Energy Needs*, HMSO, London.

(v) Conference papers: Trump, A. (1986), 'Power play', *Proceedings of the Third Annual Conference*, International Society of Power Engineers, Houston, Texas, pp. 40-51.

(vi) Newspaper articles: Popham, B. (1987), 'Saving the future', *Weekend Guardian Magazine*, 7-8 Feb., p.10.

(vii) Databases: AGRIS (database), United Nations Food and Agricultural Organisation, Vendor: Silverplatter, annual updating.

(viii) Motion pictures and videos: *Learning to Live* (motion picture) (1964), London, FineFilms Inc., Producer Martin Freeth.

(ix) Internet journal articles: Griffith, A.I. (1995), 'Coordinating Family and School: Mothering for Schooling', *Education Policy Analysis Archives,* [Online], vol. 3, no. 1, 49310 bytes, Available from URL: http://olam.ed.asu.edu/epaa/, [Accessed 12 February 1997].

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