Water Quality Profile of Swan River Himachal Pradesh, India using GIS

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Abstract: To meet the ever increasing demand of drinking water, a number of shallow tube wells are used to draw the water from upper aquifers of Swan river. In most parts of the river catchment, the current ground water extraction is exceeding the recharge rate causing the rapid depletion of shallow ground water, resulting in serious environmental hazards like land subsidence during the dry season flow and very low dilution levels in the surface water. The water becomes polluted due to domestic and industrial waste water discharges. The present paper aims to study a water quality map of Swan River based on the computations of the National Sanitation Foundation Index (NSFWQI) and the Overall Index of Pollution (OIP) using water quality data from July to December 2012. A GIS tool has been used to prepare a water quality map of the study stretch (as a function of distance) along upstream and downstream from the pollution sources. The water quality map can help planners and designers make a quantitative assessment of the problem and better suggest long term measures to improve the health of the river.

Key words: Water quality, Geographic Information System (GIS), National Sanitation Foundation NSF (WQI), Overall Index of Pollution (OIP)

Introduction

The abstraction of surface as well as ground water has increased for various uses (e.g., drinking, industrial and irrigation, etc.), not only in India but also globally. The rapid growth in population coupled with urbanization and industrialization has led to the degradation of water quality (sometimes referred to in this paper as "WQ") and the depletion of available ground water, creating an overall scarcity of drinking and irrigation water. The depletion of the water table has been studied by Sayama et al. (2005) who studied the impacts of drought and pumping on groundwater supplies and salinity intrusion. A large-scale groundwater model was developed by Kabbour et al. (2005) to assess the freshwater discharge towards the ocean and its impact on the water table due to the inverse hydraulic gradient and marine water intrusion. Subramanian et al. (2004) studied the hydrological features of surface water in the subcontinent by considering the impacts of physic-chemical parameters in South Asian Rivers. Tait et al. (2012) have conducted non-market evaluation of water quality using GIS and a random parameter log it model to evaluate the impact of water quality on willingness-to-pay for river and stream conservation programmes in Canterbury, New Zealand. They found that respondents living in the vicinity of low quality waterways are willing to pay more relative to those who live close to high quality waterways.

Oguchi et al. (2000) have studied river water quality in the Humber Catchment using GIS-based mapping and analysis and an extensive Environment Agency and Land Ocean Interaction Study (LOIS) monitoring database. Abolghasem et al. (2007) applied RS and GIS techniques to rural water supply systems in Iran and demonstrated how the technologies could be used to facilitate a more efficiently designed rural drinking network, including the locations of the storage water tank, assessment of the water quality, selection of the water source for the supply system, and considerations of ground surface properties, land use change and ownership. Donia et al. (2011) carried out water quality investigation of Lake Temsah using GIS and different water quality indices and reported that areas suitable for each use could be identified on spatial thematic maps and developed within the GIS system. They found that the middle area of Lake Temsah was found to be of good quality and suitable for all uses, especially for swimming. Al-Adamat et al. (2003) studied the groundwater vulnerability for the Basaltic aquifer of the Azraq basin in Jordan using GIS, remote sensing and the DRASTIC model.

The water quality analysis at the Bhadravathi Taluka, Karnataka, India was conducted by Rajkumar et al. (2012) based on 12 physico-chemical parameters and used GIS to represent the spatial distribution of the parameters and raster maps. The water quality was found suitable for human consumption at most locations. Water quality assessment of the Godavari River was studied by Chavan et al. (2009) reported poor and medium water quality in the studied stretch of the river. Water quality of the Ninglad stream in India was assessed by Sharma et al. (2009) based on benthic macro- invertebrates.

The above literature survey reveals that RS and GIS have not been widely used to assess the quality of rivers/streams in India and to prepare water quality maps that could be helpful for decision-makers and the general public to understand the present environmental scenario.

The main objective of the study was to develop a GIS-based map of the study area, highlighting the water quality sampling points and to provide information on the existing levels of some major water quality parameters at those sampling points. The main outcome of the paper, we believe, will be helpful to planners and designers making qualitative assessments of water problems and devising long-term measures for improving of health of the river.

The Study Area

The Swan River (known as the "river of sorrow" and a tributary of the Sutlej) flows from the north to west. Swan River Flood Management and Integrated Development (SWFMID) were launched in 1984 to control flood hazards and to convert the river to a natural gift for the people of the Una district in Himachal Pradesh (India).

Major towns located on the banks of river Swan include Gagret, Una, Mehatpur and Santokhgargh with major industrial areas located in Gagret, Mehatpur and Tahliwal. The total length of the river is approximately 85 kilometres, of which 65 kilometres fall in Himachal Pradesh. The total catchment area of the river watershed is 1400 km^2 with 80 tributaries contributing to the flow during monsoon period. The Swan is an intermittent river and maintains a base flow in the lower reaches. Eighty percent of its catchment area falls in the Una district and the river divides the district into two parts. The industrialization and urbanization along various points of the Swan has resulted in deterioration of river water quality. The Swan main source of sub soil water in the catchment used for domestic, industrial and irrigation purposes (Venu & Rishi 2011). The Swan River passes through three industrially developed areas with 49 medium-scale and 575 small-scale industrial units located on both banks. The SWFMID Project was formulated by Irrigation Cum Public Health (IPH) department in order to reclaim land by providing embankments on both sides to utilize the river water for various purposes (e.g., drinking, bathing, irrigation and fishing). In the light of significant human activities and use, it has become necessary to evaluate the river water quality.

Material and Methods

Eight sampling locations were selected in the study area along the stretch of Swan River to calculate various water quality indices. The details of sampling locations and surrounding industries were reported in our earlier paper (Sharda et al. 2012). Figure 1 includes the location map of the catchment area of Swan River, and the sampling locations and main tributaries (Holy Khad and Talhiwal Khad) that carry industrial and domestic waste water to the Swan River.

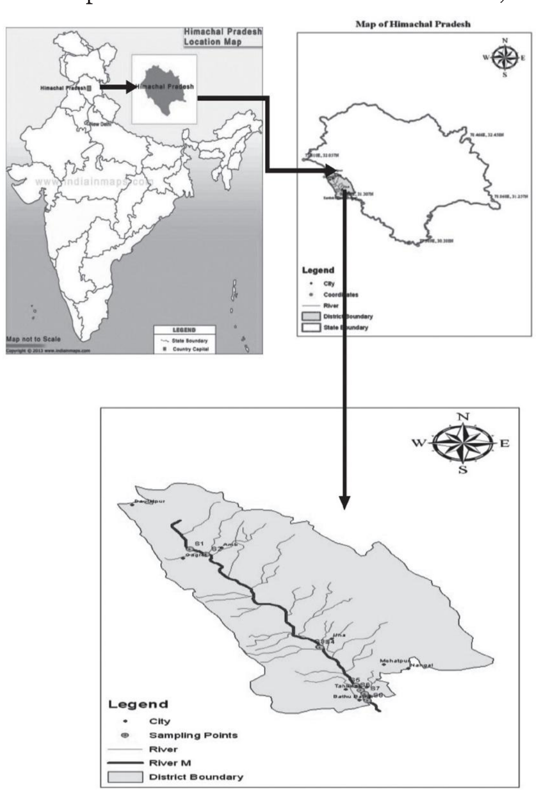

Figure-1: Location map of district UNA showing sampling locations

Table 1 lists the waste water characteristics of all three tributaries by forms of physic-chemical parameters of water quality.

S. No.	Parameters	Name of the Tributaries		
		HolyKhad	TahliwalKhad	Rampur Khad
1	pH	7.35	7.51	8.47
2	Dissolved Solids(mg/l)	1125	1219	496
3	Suspended Solids(mg/l)	62	87	41
4	Conductivity umho/cm	1360	1420	669
5	Turbidity(NTU)	63.8	98.1	5.4
6	NH_4-N(mg/l)	16.74	8.96	
7	BOD(mg/l)	360	170	24.2
8	COD(mg/l)	952	344	68
9	Hardness Total(mg/l)	499	674	338
10	Oil &Grease(mg/l)	3.08	2.6	BDL
11	Phosphate(mg/l)	0.48	0.06	BDL
12	Iron(mg/l)	0.17	BDL	BDL
13	NO_3-N	4.11	5.175	BDL
14	Lead	BDL	BDL	*BDL
Source: SPCB Una*BDL -Below Detectable Limits				

Table 1. Waste Water Characteristics of Tributarie

The data of the above table is based on the analysis of samples collected from the three tributaries carrying waste water from upriver industries engaged in fermentation, pharmaceutical production, battery production, metal finishing, and food production. The water quality parameters were converted to WQIs and compared with DBU-based classifications per CPCB and WHO standards to assess the change of water quality.

Experimental Work

Swan River is perennial source of surface water and approximately 80 tributaries contribute to the surface and sub-surface flow. The soils in the catchment area are fertile and comprised of alluvium, sand, and gravel. In the last decade the catchment of Swan River has witnessed high urban and industrial growth, creating higher levels of pollution The eight samples were collected at all locations from July to December 2012 and analysed in the State Pollution Control Board's laboratory, following standard methods (APHA 1993).The results have been already been reported in our earlier paper, where water quality assessment of Swan River using NSFWQI and OIP (Sharda et al.2013).

The coordinates of sampling locations were measured using a hand-held global Positioning system (GPS). The images of the maps showing state and district boundaries were downloaded and converted into tiff format. By creating a folder connected to the Arc-Catalogue, different shape files were created to represent varying features like state and district boundaries, rivers, major towns, drainage lines and sampling points. The boundaries of state and district were geo-referenced using Arc-GIS software and the location of Swan River and sampling points were marked on map of the Una district. The distances between sampling locations were measured using different GIS tools. Thematic layers of the major stress parameters (e.g., DO, BOD, Phosphate and pH) were prepared at each sampling location. The water quality parameters at all the locations with WQI and OIP are given in Table-2.

Sample Code	Temp	SS	pH	Turbidity	Cond.	TDS	DO	BOD	COD	T Hardness	Ca	Mg	F	PO_4	TC	F.C	WQI	Ratings	OIP	Ratings
S1	18.6	17.8	8.44	10.88	381.6	306.2	8.12	2.2	13.6	197.6	75.36	21.91	0.155	0.03	7.75	4.75	81.32	Good	1.49	Acceptable
S2	18.6	17.4	8.42	8.276	461.6	365.2	8.04	2.28	13.8	246.6	92.43	22.93	0.31	0.05	15.5	9.75	78.27	Good	1.57	Acceptable
S3	19.6	57	8.42	29.48	474.6	397	7.78	1.98	11	220	78.63	7.75	0.30	0.23	27.33	11.66	71.39	Good	1.67	Acceptable
S4	20.2	74.7	8.09	10.90	492.6	395.8	6.04	1.92	12.4	208.8	82.80	6.09	0.15	0.18	40	16.66	70.39	Good	1.79	Acceptable
S5	19.8	26.1	8.25	8.70	448.8	323	5.66	2.34	10	204.8	84.40	8.96	0.27	0.16	24.66	16	68.96	Medium	2.01	Slightly Polluted
S6	20	50	8.03	15.20	499.2	348.8	3.66	3.78	15.2	218.8	85.77	10.58	0.21	0.35	39.75	7.5	60.27	Medium	2.37	Slightly Polluted
S7	18	71.9	8.31	32.30	487.8	384.5	5.975	3.225	15.25	243.5	114.42	20.58	0.48	0.25	22.66	22.5	63.41	Medium	2.44	Slightly Polluted
S8	19.2	65.2	8.34	30.04	537.6	401.6	6.06	3.9	16.6	218.8	79.99	14.62	0.40	0.62	57	31.66	60.42	Medium	2.5	Slightly Polluted

Table 2. Segment wise WQI (Average of parameters from July to Dec 2012)

S. No.	NSFWQI		OIP		Inland Surface Waters		WHO Standards	
	Range	Quality	Limits	Ratings	Classes	DBU based Water Quality Criteria(CPCB)	Parameters	Limits
1	90-100	Excellent	0-1	Excellent	A	Drinking Water (without conventional treatment)	pH DO (mg/l)	7.0-8.0 5
2	70-90	Good	1-2	Acceptable	B	Outdoor bathing (Swimming pool-bathing ghat	BOD (mg/l) COD (mg/l)	6 10
3	50-70	Medium	2-4	Slightly Polluted	C	Drinking Water (with conventional treatment and after design)	Turbidity Coli form	5 Absent in 100ml
4	25-50	Bad	4-8	Polluted	D	Propagation wild life, fisheries(recreation &aesthetics)	TDS (mg/l) T. Hardness (mg/l)	500 500
5	0-25	Very Bad	8-16	Heavily Polluted	E	Irrigation, Industrial cooling and controlled waste disposal	Fluoride (mg/l) NO_3-N (mg/l)	1 10

Table 3. Limits and Standards applicable in India and Worldwide

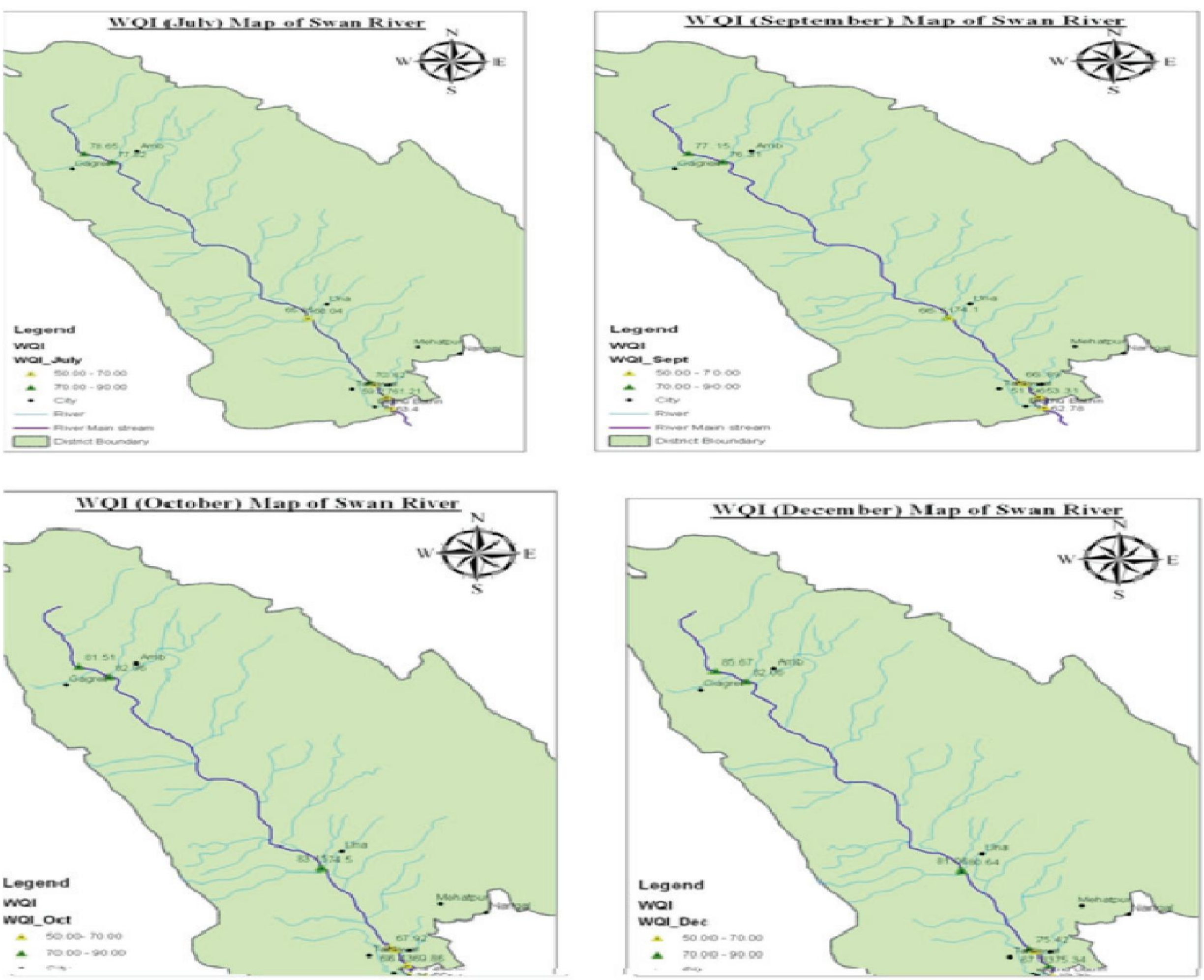

Figure 2. WQ Maps of Swan River from july to Decemebr 2007

Sample Code	July	Ratings	Sept	Ratings	Oct	Ratings	Nov	Ratings	Dec	Ratings
S1	78.65	Good	77.15	Good	81.51	Good	82.94	Good	85.67	Good
S2	77.82	Good	76.31	Good	82.96	Good	78.81	Good	82.06	Good
S3	65.85	Medium	74.1	Good	83.15	Good	72.21	Good	81.06	Good
S4	68.04	Medium	66.51	Medium	74.5	Good	76.2	Good	80.64	Good
S5	70.82	Good	66.89	Medium	67.92	Medium	71.01	Good	75.42	Good
S6	59.27	Medium	51.56	Medium	66.43	Medium	59.17	Medium	67.83	Medium
S7	63.4	Medium	53.31	Medium	69.86	Medium	69.73	Medium	75.34	Good
S8	59.75	Medium	62.78	Medium	61.52	Medium	55.33	Medium	67.79	Medium

Table 4. The values of WQI for the period from July to Dec 2012

Figure 2 and Table 4 show that there is improvement in the WQI during the month of December 2012 as compared to July and September 2012, possibly due to lower pollutant loads.

Results and Discussions

The WQ data is the average value of three replications at each location. Figure 2 is the Water Quality Map based on NSF (WQI) and parameters such as DO, BOD, PO_4^{-3}, pH and Coli form from July 2012 (pre-monsoon) to December 2012. In Table-3 we compare CPCB inland surface water with WHO standards.

Effect of Individual Stressor

The water quality data indicates that parameters such as pH, BOD, DO, COD, PO_4, Coliform have been observed as major stressor parameters in tributaries carrying effluents to the Swan River, but are within the stipulated limits prescribed under WHO standards (except d/s of sampling location S_6). The BOD and DO in this stretch is given as 3.78 and 3.66mg/l, reflecting some impact due to discharge of industrial effluents and domestic sewage upriver

Though the BOD in the study at all sampling locations conforms to the WHO limits (except coli form), but as per DBU classifications it confirms class A and C.

The BOD value reduces to 1.92mg/l d/s at sampling location S_4 (Una Town) but increases to 3.78, 3.22 and 3.9 mg/l d/s at sampling location S_6,S_7 and S_8, respectively (d/s of Mehatpur and Santokhgargh towns) due to their proximity to main urban and industrial centres. The DO was found as 8mg/l at an average temperature of 27°C (Metcalf and Eddy 1972), However, due to high organic loading, water bodies become eutrophic resulting in a higher DO concentration during the day time.

The DO conforms to desired limit of 5mg/l prescribed by WHO standards at all sampling locations except at S_6, which is downstream of HolyKhad, carrying effluents from the industrial area in Mehatpur. In the case of primary water quality criteria, DO conforms to class A and B at all sampling locations except at S_6, to class C and D, respectively.

The PO_4^{-3} values all conform to the limit of 0.7mg/l prescribed under EC standards. The $PO4^{-3}$ values range between 0.03mg/l at S1 and gradually increase to 0.62 at S8, which is d/s of Bathri and has shown impacts of fertilizer application in the catchment. Similarly, the pH at all sampling locations are also under the limit of DBU classification and WHO standards, respectively. Coliform ranges from 7.75 MPN/100ml at S_1 to a maximum of 57 MPN/100ml that may be due to discharge of untreated domestic sewage.

Evaluation of Water Quality

WQI & OIP of Swan River was assessed due to large variations in river flow during pre-and post-monsoon season (Table 2). Figure 3 gives the relation between WQI and OIP. It indicates that water quality in the river at sampling S1, S2, S3 and S4 falls under good and acceptable quality, but is further reduced from (82.2 to 70.39) and increase in OIP values from (1.49 to 1.79) shows marginal impact of industrialization and urbanization on river water quality and

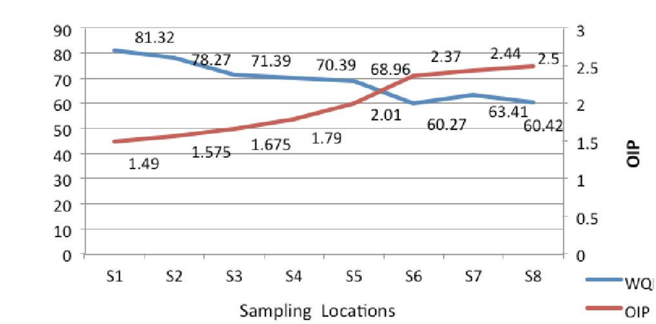

Figure 3. Relationship between WQI and OIP at the sampling locations

Water quality at S5, S6, S7 and S8 is in the medium range and slightly polluted. The intersection of WQI and OIP line indicates that water quality starts to deteriorate after S_5, (u/s of the Holy Drain indicated by point of intersection at WQI and OIP, 65 and 2.22 respectively) and with medium and slightly polluted locations. Both the indices at S6, S7 and S8 are found to be slightly polluted due to higher industrialization and urbanization discharge into the river catchment. Though the industries have their own waste treatment systems, the characteristics of the effluent make it extremely difficult to meet the statutory standards, even when industry makes a good faith effort. Other causes of pollution in the Swan River are the lack of proper management of waste water generation from domestic sources, municipal solid waste (MSW) management, and the least impacts of conservation measures. The river pollution may be addressed by setting up Common Effluent Treatment Plants (CETPs) and STPs in Mehatpur and Santokhgargh to intercept and treat waste water before it is discharged into the river, especially at S5 and S8. The proper disposal of MSW and other solid waste should be an integral part of conservation measures. This would result in an improvement in the health of river and allow the local people to make better use of treated water

Conclusion

The study manifests the importance of GIS as a tool to spatially analyse the water quality parameters involved in evaluation of NSFWQI and OIP of Swan River at various locations. The WQ map of the area was developed using WQI. The WQ maps prepared for the months of July to December 2012 show the improvement in water quality in the post monsoon period, with a maximum WQI value of 85.67 u/s of Gagret industrial area, and minimum WQI value of 51.56 at d/s of HolyKhad (in). This is due to discharge of industrial effluents and untreated domestic sewage from Mehatpur. The maps also indicate that WQ is good in the upper reaches and medium in lower reaches. The water quality map has shown that Swan River currently is suitable for organised bathing at all sampling locations except downstream of S_6 (downstream of HolyNala)

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CALENDER OF EVENTS - WATER SUPPLY

01 - 06 September, 2013: World Water Week Stockholm, Location: Sweden Organizers: Stockholm International Water Institute (SIWI) Email: secretariat.www@siwi.org , URL: www.worldwaterweek.org

04 - 06 September, 2013: Water and Society 2013, Conference/ Seminar, 2nd International Conference on Water and Society - Location: Southampton, UK. ULT: http://www.environmental-expert.com/events/water-and-society-2013-13522

03 - 07 November, 2013: Water Quality Technology Conference and Exposition (WQTC) Event American Water Works Association, Location: Long Beach, CA, USA; http://www.environmental-expert.com/water-wastewater/drinking-water/events/event-type-conference-seminar

05 - 08, November, 2013: Aquatech Amsterdam, Event Type: Conference/Seminar, Location: Amsterdam, Netherlands, URL: http://www.environmental-expert.com/ events/aquatech-amsterdam-2013-14687

25 - 27 October, 2013: Fourth International Conference on Small and Decentralized Water and Wastewater Treatment University of Thessally, Location: Volos, Greece; URL: http://www.environmental-expert.com/water-wastewater/drinking-water/events/event-type-conference-seminar

03 - 07 November, 2013: Water Quality Technology Conference and Exposition (WQTC) American Water Works Association, Location: Long Beach, CA, USA, Website: http://www.environmental-expert.com/water-wastewater/drinking-water/events/event-type-conference-seminar

CALENDER OF EVENTS - IRRIGATION

29 September - 3 October, 2013: World Irrigation Forum, Location: Mardin, Turkey, Organizers: International Commission Irrigation and Drainage, URL: www.icid.org/conf_wif.htm/

June 2014 12th International Drainage Workshop (IDW), Location: St. Petersburg, Russia, E-mail: ibond@online.ru, rusiptrid@mail.ru

CALENDER OF EVENTS - ENVIRONMENT

17 - 18 November, 2013: International Conference on Sustainable Environment and Agriculture (ICSEA 2013), Location: Abu Dhabi, United Arab Emirates, Contact person: Ms Eve Li, Organizers: CBEES, Website: http://www.icsea.org/