Is there is relationship between agricultural land value and treated wastewater irrigation for agriculture: A hedonic pricing approach

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Abstract

This present study has employed the hedonic pricing technique to calculate the value of marginal changes in the characteristic of treated industrial wastewater irrigated farm land in Tamil Nadu, India. A sample of 240 farmers was selected through multistage random sampling technique. The major findings of the analysis revealed that, the additional income obtained from agricultural land value in sample farms using treated wastewater was higher by INR 13.34 lakh while compared to control farm. As one would expect, agricultural attributes are very important determinants of agricultural land prices followed by environmental attributes and location attributes. Implicit values for transport facility, number of irrigation, bore and open well availability, land quality index and vegetative cover are embedded in agricultural land prices and there is evidence that the use of treated wastewater reuse for agriculture can improve the fit of the hedonic price regression. Distance between cisterns to farm significantly reduces the land value. In this present study emphasized that the use of treated industrial wastewater for agriculture is high potential for increasing the agricultural land value in the Tamil Nadu.

Keyword: Agricultural land value, Treated wastewater, Hedonic Pricing

1. Introduction

Water (H_20) is the most valuable/ precious/ abundant natural resource in the world. The earth's surface is covered 70 per cent by water and out of this the saline seawater is 97 per cent and only about three per cent of it is fresh water (Hossain, 2001). But, the clean or drinking water is about 13 per cent of the residual which is 0.40 per cent of all the world water and the remaining is held either as; atmosphere and ice (Jaber *et al*., 1997). The primary competing uses of water is typically agriculture irrigation followed by industrial use, domestic purpose, recreational uses and more recently preservation of environment (McCarl *et al*., 1999; Huber, 1999; Orr and Colby, 2004; Loehman and Becker, 2006).

Water scarcity is a serious issue especially for urban and industrial sectors due to inefficient water use by the agricultural sector. Better management of agricultural water use to meet future demands of the other sectors is needed. About 70 per cent of fresh water is used for irrigation in developed countries and over 85 per cent is used in low income countries (Meinzen-Dick and Rosegrant, 2001). Additional or alternative sources such as; reuse of treated wastewater in agriculture is thus required to reduce the gap between demand and supply and to supplement water shortages in future. Furthermore, the use of treated wastewater in agriculture is expected to increase rapidly over the next few decades as population increases and water deficit intensifies. Treated wastewater can be used for agriculture, commercial, residential and industrial purposes. By volume, agricultural irrigation is the largest use of reclaimed wastewater followed by water used by industrial cooling and processing (Metcalf and Eddy, 2003; Ammary, 2007; Lahnsteiner *et al.*, 2013; Mateo-Sagasta *et al.*, 2015; Arborea *et al.*, 2017).

Treated wastewater in such circumstances has high potential for reuse in agriculture; avoiding direct pollution of rivers, canals, surface water; an opportunity for increasing food and environmental security, conserving water and nutrients, thereby reducing the need for and expenditure on chemical fertilizer and disposing of industrial and municipal wastewater in a low-cost, sanitary way (Al Salem, 1996; Bahri, 1999; Kretschmer *et al*., 2000; Ammary, 2007; Pedrero *et al*., 2010; Cirelli *et al*., 2012; Ganoulis, 2012; Jaramillo and Restrepo, 2017; Lavrnić *et al*., 2017; Sathaiah and Chandrasekaran, 2020). Among different sources of treated wastewater, industrial wastewater reuse is one of the significant components of wastewater reuse in agriculture as the source content are known and treatment is done by the industry (WHO, 2006; Gori and Caretti, 2008; Adewumi *et al*., 2010; Libutti *et al*., 2018; Sathaiah and Chandrasekaran, 2020). Treated wastewater is used for agricultural irrigation that can helps to increase the land value (Urkiaga, 2006; Mekala *et al*., 2008; Sathaiah and Chandrasekaran, 2020).

Under these circumstances, the present study was taken up with the following objectives namely: 1. to compare the agricultural land value in treated wastewater irrigated farms and control farms in Tamil Nadu and 2. to estimate the factors determining the agricultural land value in treated industrial wastewater irrigated farms in Tamil Nadu.

2. Theoretical framework of Hedonic price method

Land is the "original and inexhaustible gift of nature". The supply of land is fixed quantity. The attention for land in economic theories has changed over time. The early and well-known theories of David Ricardo and, in a more spatial context, Von Thünen have laid the foundation of land price and land use theories and are to a certain extent still valid and used in current research (Randall and Castle, 1985).

The theory of economic rent in land was first proposed by David Ricardo (1773-1823). David Ricardo in his book "Principles of political economy and taxation", explained rent as that: "portion of the produce of earth which is paid to the landlord for the use of the original and indestructible power of the soil". So, rent is paid for the use of land for its original power. According to Ricardo: "all the land units are not of the same grades. They differ in fertility of land and location. The application of the equal amount of labour, capital and organizational resources give rise to differences in productivity. This difference in productivity or the surplus which arises on the superior land units over the inferior land units is an economic rent".

The bid rent theory is based on microeconomic theory and was mainly developed in the context of relationship between urban land uses and urban land values (Alonso, 1964; Mills and Hamilton, 1994). In a very simplified view, households and industries make a tradeoff between the land price, transportation costs and the use of land area. This results in a convex land price curve with the highest land prices near the urban area. The derivation of agricultural land values in the bid rent theory owes more to Von Thünen's theory (Isard, 1956) than the theory of Alonso. The highest revenue/production obtained from the particular crop at a particular location will be able to make the highest bid and thus will be cultivated on that parcel. The land is sold to households or firms if their bid is higher than the bid of agriculture; the situation which defines the limits of the urban area.

Lancaster (1966) has developed the hedonic price theory based on the theory of consumer demand. Lancaster explained that the characteristics of goods contribute to the demand decision, which is built by the consumer. Rosen (1974) was further developed to the theoretical concept of hedonic pricing including pricing models. Rosen has been widely cited and the theoretical framework developed by him has frequently been used when different consumer goods are valued (housing prices and agricultural land price valuation) (Rehdanz, 2006; Ng and Wills, 2009. Feichtinger and Salhofer 2016).

Hedonic pricing method (HPM) is admired among economists/ agricultural economists for the study of agricultural land and housing prices. It is a most powerful model, used by natural resource and environmental economists, for measuring the value of non-market goods like freshwater, air pollution or even risk condition (O'Donoghue *et al*., 2015). According to Khan *et al* (2016), agricultural land corresponds to a class of products differentiated by their locational, agricultural and environmental characteristics. This creates hedonic hypothesis that each good (parcel of land) is considered a bundle of characteristics, and its price depends on those characteristics. A number of studies have used hedonic pricing model to study the determinants of agricultural land prices (Maddison, 2000; Plantinga *et al*., 2002; Ready and Abdalla, 2005; Latruffe *et al*, 2008; Kostov, 2009; Guiling *et al*., 2009)

3. Materials and Methods

3.1. Data Collection

The data relating to the year agricultural year 2015–16 were collected for the research during the year 2017 following a multistage random sampling technique. Paper industry purposively selected in stage – I. Among the various industrial sectors, pulp and paper industry is the third largest water consuming/using industrial sector in India apart from Thermal power plants and Engineering industries (CSE, 2004). Paper and pulp industry is one of the notorious polluters of the environment. It has been categorized as one of the most polluting industries due to discharge of enormous volumes of high colored and toxic wastewater in the environment causing pollution of land (soil), air and water (Martin, 1998).

Tamil Nadu News Print Limited (TNPL) was purposively selected for the present study in the second stage since it has the largest paper production capacity at a single location in India and this is the only paper mill that provides the treated wastewater for irrigation to nearby farming villages in Tamil Nadu, India. The third stage was selection of the sample farmers. The sample size (n) of farming units in the study area is determined by applying the following formula (Arkin and Colton, 1950).

$$n = \frac{N z^2 p(1-p)}{N d^2 + z^2 p(1-p)}$$

Where: n = sample size; N = total number of farm households (638); z = confidence level (at 95% level z = 1.96); p = estimated population proportion (0.5, this maximizes the sample size); d = error limit of 5% (0.05).

Application of the above sampling formula with the values specified which in fact maximizes the sample size, yielded a total required sample of 240. A total of 240 farmers were hence selected for the present study. This consisted of (i) sample farmers irrigating their farms with treated wastewater (120 farmers) and (ii) farmers operating control farms (120 farmers). In this stage, the number of farmers to be selected was based on the probability proportion to size from treated wastewater irrigated sample farms and control farms.

3.2. Analytical Methods

3.2.1. Descriptive Analytical

Descriptive statistics namely the mean and percentage analyses besides frequency analysis were used to compare the agricultural land value in treated wastewater irrigated farms and control farms in the study area.

3.2.2. Class Interval

$$\text{Width of the class interval} = \frac{\text{Largest numeriacal value} - \text{Smallest numerical value}}{\text{Number of classes desired}}$$

In the present study, the class interval by Sharma, 2007 was used for the construction of land quality index based on productivity of particular crop. Coconut was purposively selected for the present study since it has occupied the highest cultivable land area (Sathaiah and Chandrasekaran, 2020).

3.2.3. Management Index used in Production Function

Following Makary and Rees (1981), the management index was derived for this study in the following manner. The management function (log-linear form) employed in this study was

$$\ln(Y) = b_0 + b_1 \exp + b_2 EDU + b_3 OCC + b_4 LH + e$$

where, Y is the total farm production per hectare in kgs; EXP is the total farming experience in years; EDU is the education dummy (=1, if secondary school and above and '0' otherwise); OCC is the occupation dummy (=1, if agricultural as the primary occupation and '0' otherwise); LH is the land holding in hectare and e is the error term.

Using the estimated coefficients of the function and the respective mean value of EXP, EDU, OCC and LH, the management index was worked out for all respondents, employing the following equation.

$$MI_i = \frac{\left(b_1 \exp_i + b_2 EDU_i + b_3 OCC_i + b_4 LH_i\right)}{\left(b_1 \overline{\exp} + b_2 \overline{EDU} + b_3 \overline{OCC} + b_4 \overline{LH}\right)}$$

Where, MI_i is the management index of the sample farms; b_1, b_2, b_3 and b_4 is the estimated coefficients of management function; EXP_i, EDU_i, OCC_i and LH_i is the variables used in the i^{th} farm and $\overline{\exp}, \overline{EDU}, \overline{OCC} \wedge \overline{LH}$ is the mean value of the sample farms.

Then, the estimated management index in the i^{th} farm was incorporated in the hedonic pricing model.

3.2.4. Hedonic pricing model for the estimation of land value

The hedonic pricing method is used to calculate economic benefits and costs associated with environmental services by examining market interactions for housing, land, air pollution and wages. The estimation of agricultural land value was done using an indirect valuation method known as hedonic pricing model. The hedonic pricing model involved decomposition of the price of agricultural land into the prices of various attributes. The hedonic price model for agricultural land pricing is conducted in two stages. First, the hedonic pricing model is estimated by regressing land sale prices over different characteristics. Then in the next stage, the estimated model in the first-stage is used to derive the marginal willingness to pay (MWTP) function for a land characteristic. This study is restricted to the first stage only.

We structured our hedonic pricing model for agricultural land prices based on theories of land, empirical studies and local environmental realities. The theoretical specification for the hedonic price function applied to agricultural land defines the agricultural land price vector (LP) as a function of the individual characteristics of the agricultural land according to three categories in matrix form: location attributes (L), agricultural attributes (A) and environmental attributes (E). In general form, the model is specified as;

$$LP_i = f\left(L_i, A_i, E_i\right)$$

Where, LP_i is the agricultural land price; L_i, A_i and E_i represent the location, agricultural and environmental attributes for the i^{th} agricultural land.

The marginal price of attribute in the market was simply the partial derivative of the hedonic price function with respect to that attribute. In selecting a land, buyers equated their marginal willingness to pay for each attribute to its marginal price.

Utility maximization in hedonic market had to satisfy

$$\frac{\Delta p}{\delta a_i} = \frac{\delta \theta}{\delta a_i}$$

Where Θ is the household's bid function. The equation implied that in equilibrium, the marginal willingness to pay for an attribute could be measured by its marginal price, computed from the hedonic price function.

The literature on hedonic pricing methods would suggest that quality attributes of land, distance between farm or residence from industry activity, productivity and the characteristic of households, income, etc., would influence the value of agricultural land in any region.

3.2.4.1. Chosen functional hedonic pricing model

Hedonic price model studies for agricultural farm land values mostly rely on ordinary least square estimations (OLS) (Miranowski and Hammes, 1984; Gardner and Barrows, 1985; Palmquist and Danielson, 1989; Donoso and Vicente, 2001; Maddison, 2009; Troncoso *et al*., 2010; Ay *et al*., 2012; Chicoine, 2015). A major experiential issue related to the hedonic price model is the choice of the production functional form. There are several production functional forms such as linear, double log (log-log), semi-log (lin-log & log-lin) forms and a box-cox transformation that can be applied to the hedonic price model (Xiao, 2017). For this present study, semi – logarithmic functional form used to find the determinants of land value in treated wastewater irrigated farms in Tamil Nadu (Kolowe, 2014).

$$\ln(LP) = ¿ X_i \beta_i + \mu ¿$$

Where, ln (LP) is the natural log of property price (agricultural land value), X_i is the collapsed vector for i^{th} attributes, and μ is the error term.

The semi-logarithmic functional form has many advantages over the other functional forms (Kolowe, 2014):

1. The coefficient can be easily interpreted results as the percentage change in the property price given a one-unit change in the i^{th} attributes;
2. The semi- logarithmic functional form helps to minimize the heteroskedasticity problem, dispersion and different variance problem.

In the present study, to estimate the marginal price of these attributes at the study area using semi log functional form, the hedonic model is specified as given below:

$$\ln(VAL) = \alpha_0 + \beta_0 (PROX) + \beta_1 (DCF) + \beta_2 (TF) + \beta_3 (NI) + \beta_4 (OWA) + \beta_5 (BWA) + \beta_6 (LQI) + \beta_7 (MI) + \beta_8 (VC) + \mu$$

The identification of variable, hypothesized sign and description are presented in the Table 1.

Table 1. Variable identification, hypothesized sign and description

Variable	Hypothesized sign	Variable Description
VAL	Dependent variable	Agricultural land value in INR lakh per hectare
Location Characters		
PROX	Positive	Distance between paper mill to irrigated farm in km
DCF	Negative	Distance between cisterns to irrigated farm in km
TF	Positive	Transport facility ('1' if yes, '0' otherwise)
Agricultural Characters		
NI	Positive	Number of irrigations per ha
OWA	Positive	Openwell availability ('1' if yes, '0' otherwise)
BWA	Positive	Borewell availability ('1' if yes, '0' otherwise)
LQI	Positive	Land Quality Index ('1' if poor, '2' if moderate, '3' good). The land quality index measured in terms of the productivity of particular crop. If the productivity is low the land quality index is poor; the productivity is moderated quantity the LQI is moderate and the yield is high the LQI is good.
MI	Positive	Management Index is calculated through management production function.
Environmental Characters		
VC	Positive	Vegetation tree cover ('1' if yes, '0' otherwise)
μ		Random error term

4. Results and Discussion

The results obtained from the current study are presented below:

4.1. Change in agricultural land value in the sample farms

Table 2. Change in agricultural land value in the sample farms (in lakh INR/ha.)

Sl.No	Particulars	Control farms	Sample farms using treated wastewater
1.	Agricultural land value	6.42	19.76 **(207.79)**

Note: Numbers in () indicate percentage change in sample farms using treated wastewater to control farms

The change in the agricultural land value in the sample farms presented in Table 2 would reveal that the average agricultural land value in sample farms using treated wastewater was substantially higher (INR 19.76 lakhs (US$ 26811.57)) compared to the control farms (INR 6.42 lakhs (US$ 8711.05)). Thus, the use of industrial treated wastewater for irrigation is clearly emphasized to increase in the agricultural land value in Tamil Nadu.

4.2. Factors determining agricultural land value in treated wastewater irrigated farms – results of hedonic pricing model

Hedonic pricing model (log - linear regression model) was used to estimate the factor determining agricultural land value in treated wastewater irrigated farms. The post estimation diagnostic test was needed to estimation of log – linear regression model. In this study to evaluate the outliers, multicollinearity, heteroscedasticity, spatial lag dependence and spatial error dependence. The results of the post estimation test are given in the table 3.

Table 3. Post estimation diagnostic tests - hedonic pricing model

Problems	Diagnostic tests	Results	
		Statistic	P - value
Outliers	Mahalanobis Distance	Min = 1.82	

Multicollinearity	VIF test	Mean VIF = 1.51	-
Heteroscedasticity	White test	$\chi^2 = 0.24$	0.627
Spatial lag dependence	Lagrange multiplier (LM)	LM = 0.147	0.69
	Robust Lagrange multiplier	RLM = 0.239	0.62
Spatial error dependence	Lagrange multiplier (LM)	LM = 0.001	0.97
	Robust Lagrange multiplier	RLM = 0.085	0.77

The minimum value of Mahalanobis distance was 1.82. This would be indicated there is no outlier present in the log-linear model.

Multicollinearity is a statistical phenomenon when two explanatory variables in a multiple regression model are highly correlated. There are several methods to detect multicollinearity such as VIF, Condition Number test, and Farrar–Glauber test. The present study uses the variance inflation factor (VIF) to measure the multicollinearity. The mean variance inflation factor (VIF) value at 1.51 indicated absence of multicollinearity in the model.

Heteroscedasticity is a phenomenon where the variance of the disturbance or error term of the hedonic model is unequal (Fletcher *et al*., 2000) or changes across the sample (Hendry 1995). There are several methods to detect multicollinearity such as Park test, Glejser test, White test, Breusch–Pagan test, Goldfeld–Quandt test, and Cook–Weisberg test (Gujarati *et al*, 2009). In this study, the Breusch–Pagan test was applied to detect the presence of heteroscedasticity in the error terms. The chi square test ($\chi 2$) value at 0.06 with the *p* value of 0.806 of the Breusch-Pagan test indicated the probability of rejecting the presence of heteroscedasticity (variance of the error term) in the log-linear regression model.

Tests were also conducted to check for spatial autocorrelation problem in the log – linear regression model. Spatial autocorrelation refers to the positive or negative correlation of observations based on proximity to other observations. This interconnection is a direct result of

Tobler's (1970) first law of geography that states "everything is related to everything else, but near things are more related than distant things". The existence of spatial autocorrelation does not provide minimum-variance unbiased linear estimators. There are two types of spatial autocorrelation which may be; (i) spatial error dependence and (ii) spatial lag dependence. Spatial error dependence refers to the correlated errors that occur among the independent variables. It is also called spatial heteroscedasticity. The second refers to the correlated errors that occur between the dependent variables. It could be said to be true spatial autocorrelation. The LM and Robust LM statistics were used to check for both types of spatial error dependence and spatial lag dependence autocorrelation problems. Results showed that LM and Robust LM tests were insignificant for spatial error and spatial lag dependence within 470 meters range.

Table 4. Results of hedonic pricing model on factors influencing value of land

S.No	Particulars	Coefficient	t-value	VIF
	Dependent Variable – Value of land per ha (lakh INR)			
I	**Location characteristics**			
1	Distance between paper mill to farm (km)	0.001^{NS}	1.13	1.20
2	Distance between cisterns to farm (km)	-0.032***	-2.86	1.29
3	Transport facility ('1' if yes, '0' otherwise)	0.019**	1.95	2.52
II	**Agricultural characteristics**			
1	Number of irrigation per ha	0.005***	3.12	1.43
2	Openwell availability ('1' if yes, '0' otherwise)	0.030***	3.59	2.04
3	Borewell availability ('1' if yes, '0' otherwise)	0.070***	7.79	1.38
4	Land quality index ('1' if poor, '2' if moderate, '3' good)	0.008**	2.05	1.44
5	Management index	0.005^{NS}	0.46	1.07
III	**Environmental characteristics**			
1	Vegetative cover ('1' if yes, '0' otherwise)	0.023**	2.19	1.24
	Constant	6.282***	137.55	
	Adjusted R^2 value	0.70		
	F value	37.21***		

Note: VIF = Variance Inflation Factor; *** - 1 % level of significance;
** - 5 % level of significance; * - 10 % level of significance; NS – Non Significant

The results of hedonic pricing model are given in table 4. Results showed that coefficients for variables that describe location of agricultural land had the expected signs and were statistically significant. Distance between cisterns to farm had a negative significant coefficient. The coefficient value of -0.032 would indicate that holding other variables constant, the price of agricultural land would decrease by 0.032 per cent with increase in distance between cisterns to farm by one kilometer. It showed that agricultural land located near cisterns would have a higher price compared to one located faraway. The coefficient value for transport facility was 0.019 and was statistically significant at five per cent level of significance. The positive coefficient value implies that holding other characteristics constant, the price of an agricultural land would be higher when road facilities are present.

Agricultural characteristic is judged with land potential to produce crops. Results revealed that the coefficient for number of irrigation was positive and statistically significant. The coefficient value of 0.005 indicated that holding other characteristics constant, the price of agricultural land would increase by 0.005 per cent for every additional irrigation unit. The coefficients for open well and bore well availability were positive and statistically significant at one per cent level. The availability of open well and bore well would lead to higher agricultural land value. The coefficient for land quality index was positive and statistically significant at five per cent. The coefficient value of 0.008 indicates that holding other characteristics constant, the price of agricultural land would increase by 0.008 per cent as the index increased by one level.

In environmental characteristic namely, the coefficient for vegetation cover was positive and statistically significant at five per cent. It would indicate that holding other characteristics constant, the price of agricultural land would be increased when the green cover increased.

Also there were similar results in researches carried out by Khan *et al* (2016). However, the study by Khan *et al* (2016) the agricultural land price is affected positively by soil fertility, amount of irrigation water and closeness to agricultural market. Among location characteristics, distance to city and distance to nearest houses have positive significant effects on land prices. Agricultural land located closer to city, main road or houses has significantly higher price compared to a more distant land. Environmental degradation such as polluted freshwater bodies has negative effect on nearby agricultural land prices.

5. Conclusion

This present study makes an attempt to examine the determinants of neighborhood services on agricultural land value in treated industrial wastewater irrigated farms in Tamil Nadu through analysis based on results obtained from hedonic pricing regression analysis. Tamil Nadu Newsprint and Paper Limited (TNPL) located in Karur district of Tamil Nadu state was purposively selected for the present study. A total of 240 farmers were selected which consisted of; (i) sample farmers irrigating their farms with treated wastewater (120 farmers) and (ii) farmers operating control farms (120 farmers). The data relating to the year 2015-16 were collected for the study during November – December 2016 with multistage random sampling technique.

In an area like India, where the industrial treated wastewater has high potential for reuse in agriculture; to increase the availability of water, the number of irrigation, vegetative cover and fertility of land. According to Ricardian theory of rent, the fertility status of land is increases accordingly the economic rent of the land also increases. The major findings of the analysis revealed that, the additional income obtained from agricultural land value in sample farms using treated wastewater was higher by 207.79 per cent while compared to control farm. In this present study also emphasized the Ricardian theory of rent.

As one would expect, agricultural attributes are very important determinants of agricultural land prices followed by environmental attributes and location attributes. Implicit values for transport facility, number of irrigation, bore and open well availability, land quality index and vegetative cover are embedded in agricultural land prices and there is evidence that measure of treated wastewater reuse in agriculture can improve the fit of the hedonic price regression. Distance between cisterns to farm significantly reduces the land value. Even through some results in this hedonic pricing analysis may be questioned, as the non-linear relationship with the distance between paper mill to farm and management index, which could be raised. In this present study emphasized that the use of treated industrial wastewater for agriculture is high potential for increasing the agricultural land value in the Tamil Nadu. Therefore, government or policy makers may bring in policies to encourage use of treated wastewater for irrigation in World.

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Appendix I

Procedure for Selection of Sample Farmers

S.No	Treated Wastewater Irrigated Villages			Control Villages		
	Name of the villages	No. of farmers		Name of the villages	No. of farmers	
		Total	Sample farmers		Total	Sample farmers
1	Moolimangalam	130	52	Moorthipalayam	52	19
2	Pandipalayam	26	10	Masagoundanpudur	60	21
3	Pazhamapuram	52	21	Thaneerpandalpudur	38	13
4	Thadampalayam	60	24	Poolampalayam	68	24
5	Ponnaiyagoundanpudur	33	13	Alampalayam	47	17
6				Adhiyaman Kottai	72	26
	Total	**301**	**120**	**Total**	**337**	**120**

Source: Sathaiah and Chandrasekaran, 2020

Appendix II

Water use Scenario for TNPL

Sl. No	Particulars	Quantity (kl/day)
I	**Water Consumption**	
A	**Overall water consumption**	**54,477**
B	**Processed water consumption**	**41,152**
a	Pulp mill	14,442
b	Paper machine and CAP	13,055
c	Soda recovery plant	5,273
d	Soft water for process	1,604
e	others	6,778
C	**Cooling water consumption**	**10,027**
a	Water used for boiler feed	3,376
b	Water used for cooling purpose	6,651
D	**Domestic water**	**3,298**
E	**Processed water consumption per unit (MT) of products**	
a	Printing and writing paper	50 kl/ tonne
F	**Section wise wastewater generation**	
a	Bagasse yard	5,039
b	Pulp mill	26,942
c	Soda recovery plant	5,200
d	Paper machine	8,900
e	Others (ETP, WTP, etc)	7,950

	Total effluent generation	**54,031**
G	**Total treated effluent quantity discharged for irrigation**	**27,089**
H	Water consumption	1,98,84,105 kl/year
I	Wastewater generation	1,97,21,315 kl/year
J	Treated wastewater	1,97,21,315 kl/year
K	Treated wastewater discharged for irrigation	**98,87,485 kl/year**

Note: kl – kilo liter
Source: Sathaiah and Chandrasekaran, 2020

Appendix III

Treated wastewater irrigation water cycle

Source: Sathaiah and Chandrasekaran, 2020