An Economic Analysis on Groundwater in India

Suman Chakraborty, Arpita Chaudhury, and Riddhima Panda

Abstract The country India is one of the highest groundwater extracted country in the world. We generally use 25% out of all groundwater extracted countries, which is ahead of the US and China. The high level demand or need for groundwater implies the necessity of capability to fulfil that demand in an equitable and sustainable way. In-sufficiency of water resource is likely to deteriorate, compared to growth rate of population in near future period in our nation. To address the issue of healthy water scarcity, masses need to be conscious about water storage, water reuse and common practices to reduce water pollution. Proper valuation and pricing of groundwater is an essential tool to protect the groundwater in India. Dynamic decision on price of ground water involves to pricing the value of the vital resource ground water. Enormous extraction of the resource can shrink surface water flows and declining the quantity of water available for other uses. Strategic externality depends on behaviour of extractors of groundwater. We have got a significant relationship between irrigation intensity and cropping intensity. Yield of paddy significantly depends on water productivity. The food grain production can be increased by improved water productivity. Increased food grain supply can fulfil the domestic demand and contribute on G.D.P (i.e.,Gross Domestic Product) of the nation. So that if we wish to gift healthy Nation to our future generation we have to think how to maintain the healthy groundwater.

Keywords Cropping intensity index · Externality · Groundwater · Irrigation intensity index

S. Chakraborty (✉)
Department of Economics, Raja N. L. K. W. College (A), Midnapore, W.B 721102, India
e-mail: sumanchakraborty404@gmail.com

A. Chaudhury
General Studies, University of Engineering and Management, Kolkata, W.B 700160, India

R. Panda
Department of Business Administration, University of Engineering and Management, Kolkata, W.B 700160, India

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1 Introduction

In the present era issues of groundwater is as the cloud in the blue and shining sky. In this era sustainable development is a most vital topic but we are not so much worried about the most vital resource that is groundwater resource. The resource is also the vital economic resource of any nation. So to present a healthy nation to our future generation we have to think how to maintain the healthy groundwater. It is our key objective to take care about the flow of groundwater. The availability of groundwater and the present condition of groundwater is in an alarming condition in India, i.e.; if we don't take care about it our future generation will be suffered badly. One of the most vital resource groundwater is astonishingly undervalued and underappreciated in our country (Berry and Bonen 1974).

Groundwater is continuing to use as a dependable resource for a several of purposes, such as industrial, domestic and irrigation. According to Burke, generally use of high quality groundwater for harvesting (irrigation) offsets other uses. Aquifers are degraded by industrial waste, disposal of human beings, pesticides etc. (FAO (2003) Groundwater management).

The high level demand or need for groundwater implies the necessity of capability to fulfil that demand in an equitable and sustainable way. But the economic worth of ground water is not understood and the power conflict regarding ground water till date looms as a huge problem. It can be said that, India is a groundwater related country. We generally use 25% out of all groundwater extracted countries, ahead of the US and China (Hindustan Times Mar 11, 2019, 19:36 IST).

The value of a resource is defined in terms of quantity of other resources/money, in modern societies, currency is typically the unit used for this exchange. Sometimes the value or worth of groundwater might be higher than or a lesser amount than the market price of an economy. Most environmental resources, including groundwater, are prime examples of 'non-market' resources. While there is a market for the groundwater abstracted (e.g. public supply), there is no market for many of the other benefits of groundwater. It is a well-established fact that the access to good quality reliable irrigation is important as it not only reduces risks faced by the rain fed agriculture; it also declines the cost and enhances the production (Dhawan 1988). Another significant fact is the equity in access to groundwater under the influence of surface water, which is the most vital factor of production and limited. In India, since the land distribution is biased in favour of big farmers, there is a natural inequality in ownership as well as access to groundwater. The utility of ground water depends on fundamentally on cost of producing obtaining the water and its value in the uses to which it is ultimately put. The cost of producing ground water involves cost of extractions, delivery and opportunity cost of using the water right away rather than leaving it in storage for future use. Huge extraction of the resource groundwater for harvesting has led to extensive over abstraction of groundwater which is untenable in the long period (A Sarkar 2011). We have shown a significant relationship in between irrigation intensity and cropping intensity by simple regression model. In this chapter we have analysed the economic impact of ground water on Indian economy and the related issues and also we have recommended few alternative strategies to balance the ecology or ecosystem.

In the Circumstances Our Major Objectives Are as Follows:

(1) To find out the present condition of groundwater.
(2) To analyse the economic impact, economic valuation and also the pricing methods of groundwater.
(3) To examine a significant relationship between irrigation intensity and cropping intensity.

2 Methodology

To accomplish the concerned objectives of our study secondary data were collected. The necessary secondary data has been collected from published sources such as, books and journals, articles, RBI reports, government reports, websites, economy survey government of India, socio-economic survey report of India. We have also used the different farm efficiency index such as, cropping intensity index, irrigation intensity index we have also used water productivity concept and the important statistical techniques to analyze and interpret the data. The various tools such as mean, frequency distribution, regression analysis have been used.

(1) Irrigation Intensity (I.I) = [{Total (Gross) Irrigated Area/Net Irrigated Area Sown}* 100] and,
(2) Intensity of Cropping (C.I) = [{Gross Cropped Area/Net Area Sown}* 100] (Directorate of Economics and Statistics Department of Agriculture, Cooperation & Farmers Welfare Ministry of Agriculture & Farmers Welfare Government of India).
(3) To examine the factor relationship regression analysis is used wherever it is necessary. Regression analysis is the most important way to estimate the exact relationship between dependent variable and explanatory variable.

Now, an equation of the linear regression line can be written as, $Y = (a + bX)$; here $\boldsymbol{Y}$ is the dependent variable and $\boldsymbol{X}$ is the explanatory variable. 'b' and 'a' are the slope and the intercept of the regression line respectively. The adjusted R^2 and F of the estimated regression equation of this model are such that the relevant regression model is fitted to the data set.

(4) Water Productivity: The concept of water productivity started gaining importance since the realization of increasing threshold being faced by countries and regions on account of its available water resource, particularly with respect to the huge allocation towards agriculture sector.

The water productivity will be analyzed from three broad perspectives such as

Physical water productivity = (crop output per unit of total consumptive water used (TCWU)), Irrigation water productivity = (crop output per unit of irrigation water applied by farmers) and.

Economic water productivity = (value of crop output produced per unit of TCWU as well as irrigation water applied) (Gulati, Mohan, Manchanda, Ray, and Amarasinghe; NABARD-ICRIER 2018).

The chapter is based on following subsections. Subsection first, analyses the availability and extraction of groundwater in India. Subsection second, explains the level of water fluctuations of groundwater of wells in India. Subsection third, analyses the valuation or pricing methods of groundwater in India. Subsection fourth, explains the economic impact of groundwater of India. Subsection fifth, analyses the relation between intensity of cropping and intensity of irrigation. Subsection sixth, makes summary and conclusion of the chapter.

3 The Availability and Extraction of Groundwater in India

Groundwater is still a vital source of life in many parts where surface supply water is scarce or expensive (Patel and Krishnan 2009). The problem of Groundwater has provoked more because of uneven distribution of surface water supply around the year and in between the years.

We Indians are thinking about modern cashless economy but we are not so much worried about availability and extraction of groundwater. We have to think about use of groundwater for extraction of groundwater for the betterment of India and also for our next generation. According to the statistics of groundwater we have got in India the availability of surface water is higher than groundwater. It is observed that 89% of groundwater is using for purpose of irrigation, followed by domestic use (9%) and industrial use (2%) (W and R Statistics, April 2015, C. W. C; PRS). 50% and 85% of water requirements of urban and rural for domestic purpose are also fulfilled by ground water respectively (Central Water Commission; PRS and Suhag, 2016, The status of ground water: Extraction exceeds recharge).

It is seen that the water accessibility of India as natural flow in rivers is 1,869 (B.C.M) Billion Cubic Metres/year (April 2015, C.W.C; PRS). The usable water resources of the nation have been estimated as 1,123 B.C.M/year due to inequality of distribution of the resource in various river basins. It is seen that, contributions of surface water and groundwater are 690 B.C.M per annum and 433 B.C.M per annum out of the entire accessibility of water resource respectively (Central Water Commission; PRS.). It is clearly observed that the availability of ground water is least compared to other sources of water in India (Table 1).

Table 1 Water resources in India

Items	BCM/Year
Availability of water per annum	1869
Groundwater	433
Surface water	690
Usable water	1123

Sources Water and related statistics, April 2015, Central Water Commission; PRS

3.1 Level of Water Fluctuations of Groundwater of Wells in India

This subsection of the chapter can be analysed in two ways. Firstly we can discuss level of water fluctuation in November 2016 compared to November 2015 and then we can go for a comparison of depth to level of water of November 2016 with the decadal (2006–2015) mean of November.

Level of water Fluctuation in November 2016 Compared To November 2015:

The level of water fluctuations of november 2016 compared to november 2015 depict that out of 14,291 wells, 6322 (44%) are showing rise and 7807 (55%) are showing fall in terms of level of water. Rest of 162 (1%) stations are remaining same in terms of level of water. It is seen that 31% wells (4491) are showing rise in the level of water in the range of level of under 2 m (metres). It is clearly observed that, 8% wells (1065) illustrate rise in level of water in the range of 2–4 m range and 5% wells (766) represent rise in level of water of greater than 4 m (metres) range. 55% wells are depicting decrease in level of water, out of which 41% wells (5885) are representing decrease in level of water in the range of under 2 m (metres). 9% wells (1263) are illustrating decrease in level of water in the range of 2–4 m (metres) 0.5% wells (659) are depicting decrease in level of water of greater than 4 m (metres) range. Majority of the wells are illustrating rise/decline falls in the range of 0–2 m (metres) (Fig. 1) (C.G.B. Ministry of W. R. Govt of India, November 2016).

A Comparative Scenario of Depth To Level of water of November 2016 With Decadal Mean of November (2006–2015):It indicates that, out of 14,884 wells analyzed, 6043 (about 41%) of wells are depicting rise in level of water, out of which 31% wells are illustrating rise of less than 2 m (metres). It is seen that 6% wells are representing increase in level of water in the range of 2–4 m (metres) and 4% wells are illustrating increase in level of water in the range of greater than 4 m (metres). 8818 (59%) wells are illustrating decrease in level of water, out of which 43% wells are depicting decline in water in the range of 0–2 m (metres). It is also seen that, 10% wells are illustrating decline in level of water in the range of 2–4 m (metres) and rest of 6% wells are in more than 4 m (metres) range (Table 2 and Fig. 2) (C.G.B Ministry of W.R Govt of India, November, 2016).

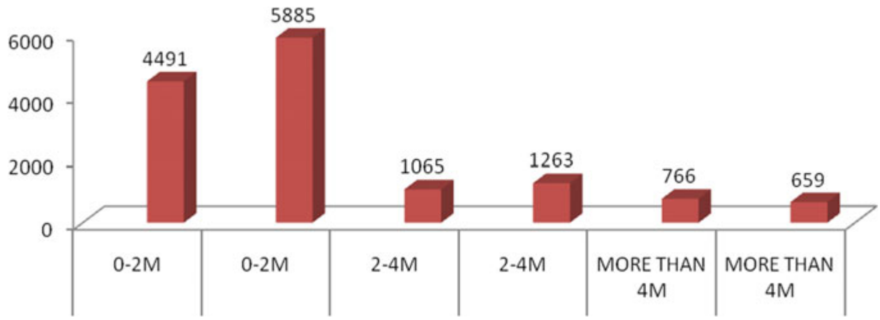

Fig. 1 Annual fluctuation and frequency distribution of different ranges from November 2016–November 2015 in India. *Sources* Central Ground Water Board Ministry of Water Resources Government of India November (2016)

4 Valuation or Pricing Methods of Groundwater in India

At present emerging and developing economies are encountering grave problems to provide supply safe drinking water to its citizens. (Hernández 2013).

The economic value of groundwater is increasing day by day due to high level of pollution of surface water, high level of population growth. So that economic value should be analysed properly and we have to think in future economic or socio economic impact of groundwater in India. The economic value of groundwater resource can be judged by its usability.

Total economic value can be segregated in two major components such as, use and non-use value. Use value is associated with physical interaction or dealings. It may be direct or derived. The term direct use represents direct physical interaction with the resource or extractive use of the particular resource where as the term indirect use shows derived value from the resource. Non-use value deals with satisfaction level of the particular resource or existence value or inheritance/bequest value.

Ground water can be pricing by many methods. Here we have shown the method of the dynamic price of ground water.

4.1 The Dynamic Price of Ground Water

A dynamic decision on price of ground water involves the optimal time rate of use (exploitation) of a natural resource. Optimization of time rate of natural resources is a complex dynamic decision to be made which involves balancing the marginal benefit (Additional benefit due to use of one extra unit of the product) and marginal costs (Additional cost due to use of one extra unit of the product).According to National Research Council, we can state that the marginal cost of extraction can be segregated in three types. These are,

Table 2 Fluctuation and frequency distribution of different ranges from November 2016 to Decadal Mean November (2006–2015)

No. of wells analysed	Rise						Falls						Rise		Falls	
14884	0–2M		2–4M		More than 4M		0–2M		2–4M		More than 4M					
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
	4590	31	907	6	546	4	6417	43	1468	10	933	6	6043	41	8818	59

Sources Same as above

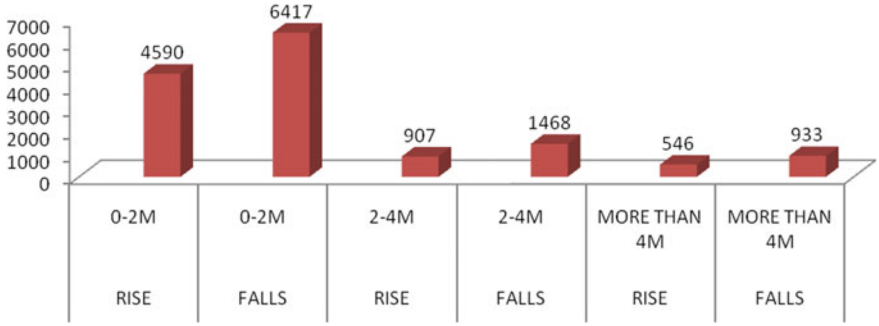

Fig. 2 Fluctuation and frequency distribution of different ranges from November 2016 to decadal mean November (2006–2015)

(1) Marginal pumping and distribution cost C(S).
(2) Opportunity cost of current extraction.
(3) Dynamic cost of pumping water includes usual cost of extraction and distribution along with opportunity cost as well as the cost of driving up future pumping cost.

Let us assume, a single owner "A" owns a confined aquifer, with no recharge, that is a finite exhaustible resource like mineral deposit. Now, 'W' is the stock of water left in aquifer after 't' periods of extraction or pullout. 'E' denotes the amount of water extracted or eroded by the firm in 't' periods. Again, let, P is the price of extracted water sold per unit and 'C' is the unit cost of pumping and distributing 'W' gallons of water. Thus the total cost can be written as (E*C) at 't' periods. The major goal of a private water supply company is to maximize the present value of extraction which requires the marginal gains of extraction should be equal to the rising costs of removal, and marginal benefit will be P, the price per unit of extracted water sold for (National Research Council 1997).

Now, $P = C + C*$.

Where, 'C*' is the dynamic cost at period t. The dynamic cost of water raises as the ground water is exhausted. Increasing scarcity of water is reflected by increase in dynamic term C*.

If we deflate the price (P) by the base year price level (p*), we will be getting the real price.

Then the above Equation can be written as,

$$P/p* \;=\; (C/p*) + (C*/p*)$$

Here, (C*/p*) is the dynamic cost at period 't' in real term. The dynamic cost of water raises as the ground water is exhausted. Balancing marginal price and marginal extraction cost yields, (C/p*) rises while 'W' declines with continuous extraction. Increasing scarcity of water is reflected by increase in dynamic term (C*/p*).

If recharge of groundwater is considered, it will change the details of the model, but not its fundamental concept. In real term if the water stock is unchanged when aquifer enters a steady state, then price of water is constant and equal to stable extraction and dynamic costs (C/p*) + (C*/p*) (assuming energy and other costs remain stable). (C*/p*) is equal to zero, if aquifer discharges naturally to the stream, and then groundwater is not scarce. The term (C*/p*) also denotes the rental value of the ground water stock at real term. It is the value that the market places on additional groundwater resources which depends on objective of society. Magnitude of C* depends on various things. C* depends on the stock of water. If other things remain constant, as the stock go up, C* goes down and vice versa. Contamination or infectivity events can decline usable water supply that will drive up the dynamic water price, C*.Cases where contamination makes ground water inappropriate for some purpose, say, drinking, but leaves it acceptable for another purpose, say, irrigation, can bring changes in dynamic prices as the stock relative to the second demand will rise (National Research Council 1997).

4.2 Economic Impact of Groundwater of India

Socio-economic impacts of groundwater depend on future water demand and supply of groundwater (mbda.gov.au). The high salinity levels of the region and high costs of drilling lead to enhance price of ground water. The agricultural product which is directly or indirectly related to the groundwater would be higher cost oriented product. Input cost of agriculture can push the price level in the economy. i.e.; Agflation (Inflation in Agriculture produce) can be occurred.

According to minor irrigation census of 2001, there is an improvement in the ground water irrigation mediums in the country in the form of wells and tube wells. This has depicted in 60% reduction in the share of surface water (Shankar Vijay 2011).

Social cost will increase due to lack of healthy groundwater. The total stock of aquifer will be declined due to extraction of an extra unit of groundwater. So that, marginal costs of all extractors can be increased in future. It may create two consequences for both the extractor and all other users. Low level stock can increase the depth to groundwater and also the energy cost (costs for pumping) of all related users. This higher costs lead to negative externalities. Again low level stock reduces future availability and withdrawal (extraction) alternatives for all users. Strategic externality which is related to the pumping cost externality depends on behaviour of extractors of groundwater (Negri 1989).The economic impact can be analysed by using a regression analysis between water productivity and yield of paddy of selected countries. Here we have chosen four countries such as, China, India, Indonesia, and Bangladesh to establish a regression model.

The current limelight of water productivity has evolved to include the advantages and costs of water used for harvesting in global and aquatic ecosystems (Molden et al. 2007). In the broadest sense, it reflects the objectives of achieving more socio

Table 3 Overall water productivity and yield of paddy of selected countries in 2014–15

Country	Water productivity	Yield of paddy (t/ha)
China	14	6.8
Bangladesh	4	4.6
India	3	3.6
Indonesia	8	5.1

Source ADB, 2017, FAO aqua stat. And Agricultural Situation in India, VOL-LXXV, APRIL, 2018, NO-1. Directorate of Economics and Statistics Department of Agriculture, Cooperation & Farmers Welfare Ministry of Agriculture & Farmers Welfare Government of India; China—NBS (National Bureau of Statistics of China)

economic and ecological advantages at less cost of social and environmental for each unit of water consumed (Sharma et al. 2013). Improving water productivity in agriculture is the cornerstone of any water demand management in India (Sharma et al. 2018).

China has one of the highest values of water productivity and also for the amount of yield of paddy, followed by Indonesia (Table 3).India has one of the lowest values of water productivity and also for the amount of yield of paddy (Table 3).We have assumed Water Yield of Paddy (Y.P) as dependent variable and Water Productivity (WP) as independent variable (Table 3).

Regression equation concerning Water Productivity (W.P) and Yield of Paddy (Y.P) shows that the variation in Yield of Paddy (Y.P) is significantly explained by the Water Productivity (W.P) to the extent of 92%. It is also observed that coefficient of the variable Water Productivity (W.P) is significant at the level of 5%. The whole model is also satisfying at 5% level of significance (Table 4). Thus it can be said that, yield of paddy (Y.P) significantly depends on water productivity (W.P). Hence we can state that, the improved water productivity can enhance the food grain production. Improved food grain production can fulfil the domestic demand as well as contribute on G.D.P (i.e., Gross Domestic Product) of the economy.

The values in parenthesis are the "t" values.

Y.P—Yield of Paddy.

W.P—Water Productivity.

Table 4 Regression equation between Yield of Paddy (Y.P) and Water Productivity (W.P) in 2014–15

Regression equation	$AdjR^2$	F
$Y.P = 0.26W.P^* + 3.14$ (5.9) (8.4)	0.92	34.6*

* indicates significance at the level of 5%

5 Relationship in Between Cropping Intensity (C.I) and Irrigation Intensity (I.I)

Here, we have shown a regression analysis to examine the relation between Irrigation Intensity and Cropping Intensity of Indian economy for the year 2014–15.We have taken the relevant data from the states of our nation (India) to establish the relation. We have assumed Cropping Intensity as dependent variable and Irrigation Intensity as independent variable (Table 5).

Regression equation concerning Cropping Intensity (C.I) and Irrigation Intensity (I.I) shows that the variation in C.I is significantly explained by the I.I.to the extent of 35% and the coefficient of the variable I.I is significant at 1% level. The entire model is satisfying at 1% level of significance (Table 6).Thus Intensity of Cropping (C.I) significantly depends on Intensity of Irrigation (I.I).

The values in parenthesis are the "t" values.

C.I—Cropping Intensity.

I.I—Irrigation Intensity.

6 Summary and Conclusion

Excessive water use over the last decade has made an alarming situation for future generation as well as for our nation. It is seen that in the last decade (2001-'11) national per head or per capita accessibility of water has declined from 1,816 cubic metres to 1,544 cubic metres.This is a reduction of 15%. It is observed that, out of 14,884 wells analyzed, 41% of wells are depicting rise in level of water, out of which 31% wells are illustrating rise of less than 2 m. It is seen that 6% wells are representing increase in level of water in the range of 2–4 m and 4% wells are illustrating increase in level of water of more than 4 m range. 59% wells are illustrating decrease in level of water, out of which 43% wells are depicting decline in water in the range of 0–2 m. 10% wells are illustrating decrease in level of water in the range of 2–4 m and rest of 6% wells are in more than 4 m range (Table 2 and Fig. 2).

To address the issue of healthy water scarcity, masses require being aware about water storage, water reuse and common practices to reduce water pollution. One of the vital economical, feasible and facile method for water storage and reuse is rainwater harvesting. According to recommendation of M. S. Swaminathan in his ever green revolution rain fall water should be used in harvesting. Ground water can be charged a particular rate of price by installation of meter rather than a licensing system. Dynamic decision on price of ground water involves to pricing the value of the vital resource ground water. Another vital analysis is the marginal value of positive or negative externalities in the environment. Yield of Paddy significantly depends on Water Productivity. Thus it can be said that, the improved water productivity can increase the food grain production. Increased food grain supplies can fulfil the huge domestic demand and contribute on gross domestic product of the nation.

Table 5 State-wise cropping intensity and irrigation intensity in 2014–15

States	Irrigation intensity	Cropping intensity
Andhra Pradesh	132.76	123.3
Arunachal Pradesh	100.00	132.8
Assam	126.35	144.4
Bihar	176.36	145.4
Chhattisgarh	121.90	122.4
NCT of Delhi	131.82	161.5
Goa	100.00	122.0
Gujarat	142.07	124.0
Haryana	195.83	185.6
Himachal Pradesh	170.80	167.0
Jammu and Kashmir	152.27	155.3
Jharkhand	106.76	112.2
Karnataka	116.63	121.9
Kerala	113.53	128.5
Madhya Pradesh	107.48	155.1
Maharashtra	132.00	135.3
Manipur	100.00	100.0
Meghalaya	158.02	120.0
Mizoram	131.25	100.0
Nagaland	109.28	130.3
Odisha	117.95	115.6
Puducherry	169.23	168.3
Punjab	188.37	190.8
Rajasthan	129.04	138.3
Sikkim	100.00	176.0
Tamil Nadu	124.50	124.4
Telangana	146.52	121.5
Tripura	146.84	189.3
Uttar Pradesh	145.70	157.5
Uttarakhand	164.24	156.7
West Bengal	183.75	185.0

Source M. Of and F.W. (i.e., Ministry of Agriculture and Farmers Welfare), Government of India and RBI report

Table 6 Regression equation between irrigation intensity and cropping intensity in 2014–15

Regression equation	$AdjR^2$	F
$C.I = 0.57 I.I^{**} + 63.9$ (4.2) (3.34)	0.35	17.43**

** indicates significance at the level of 1%

Regression equation concerning Cropping Intensity and Irrigation Intensity shows that the Cropping Intensity significantly (1% level) depends on Irrigation Intensity. The entire model is satisfied at 1% level of significance. Huge extraction of groundwater can harm our society. It can damage the ecosystem by reducing surface water flows by linkage effect (hydrologic linkages). It is also declining the quantity and quality of water available for other uses. The stock externality depends on its use value. It is the part of F.M.O.C(I.E., full marginal opportunity cost) of extracting groundwater (Reineltb, Brozović c and Whittena a. CSIRO E Sciences, Canberra, E. Q, Reesona, Australia; b. St. Univ: of N. Y, Fredonia, USA; c. Univ:of Illinois at Urbana-Champaign, USA; d. Fenner School of Env: and Society, ANU, Canberra, Australia).The averting expenditures method was applied via a mail survey of households in which water contained the unregulated volatile organic chemical, per chloro ethylene (Abdalla 1990). The existence of groundwater stock to use in combination with random (i.e., stochastic) surface water supplies may create a buffer value (Tsur, Graham-Tomasi 1991). In the case of risk averse extractors, a risk externality might arise because low level stock increases the income variability tied to random (i.e., stochastic) surface water supplies as low level stock of groundwater are less capable to buffer against supplies of random (i.e., stochastic) surface water (Provencher and Oscar 1993). So that healthy flow of groundwater is inevitable factor of our nation to achieve the sustainable development.

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