**Paper 2**

# Valuating agricultural water use and ecological services in agrarian economies: evidences from eastern India

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## Abstract

Agricultural water use in agrarian economies is often state subsidized for the enhancement of agricultural productivity while poverty alleviation is also targeted. The Indian agricultural dependent states offer representative examples of undervalued irrigation services mainly sourced by canal networks. However, the current inefficient operation of canal irrigation systems diverts water demand to private initiatives by significantly increasing economic value of agricultural water. The additional recent acknowledgement of economic value encompassed in supportive ecological services enhances the request for reevaluation of agricultural water. The paper attempts to assess the value of irrigation and related ecological services in representative backward clusters of Bihar state in Eastern India. The effects on different landholding groups are analyzed by giving particular emphasis to marginal landholders.

**Keywords:** Agricultural water use, irrigation services, ecological services, valuation, marginal farmers, Eastern India

## Introduction

Agricultural water use value is customarily defined through the water demand for crop production (Hanemann, 2006). A practical approach is the division of net crop value output with the estimated water input. Under competitive market conditions, an efficient valuation of agricultural water use should be attained through the maximization of crop productivity until profits will be diminished (Tsur, 2009). The revenues from agricultural produce should allow farmers to effectively undertake the costs of irrigation services through an efficient pricing mechanism. Namely, the labor, capital, operational and maintenance costs of the irrigation system should be sufficiently covered while funding for reinvesting in new projects should be ensured. However, the objectives of irrigation policy in agrarian economies are not always aligned with the theoretical background of agricultural water use value.

The economic value of water use is de-linked from crop profit maximization by mostly pursuing an equitable minimum water volume for staple crops (Ataman and Beghin (Ed.), 2005). Sound examples are spotted in agricultural dependent states of eastern India where water sufficiency in rice and wheat crops is highly prioritized for the sustenance of subsistence farmers. To this end, low water tariffs usually conveyed through a flat payment rate are introduced in most of the agricultural Indian states for the affordability of water charges (FAO, 2006).

However, low water tariffs often result in poor operational and maintenance funding by in turn leading to inefficient supply services (Meinzen-Dick et al, 2002). The dysfunctional canal irrigation networks are giving priority to privately owned groundwater pumping (Davis et al, 2008). Rapid construction of private tube wells and installation of diesel pumping devices are nowadays profoundly apparent in North and Eastern India (Shah et al, 2009). However, the private groundwater initiatives steeply increase the actual irrigation costs which becomes hardly affordable for subsistence farmers.

The expansion also of groundwater pumping in high permeable alluvium derived soils met especially in Eastern India has induced water pollution from agrochemical residuals. Further, over pumping practices have diminished groundwater reserves by provoking erosion and salinization effects (Sharma et al, 2009). The close linkage of ground with surface water sources has resulted in an overall degradation of water status. A quantitative and qualitative deterioration has mostly affected the ecological services associated with water cycle. Indicatively, the services related with natural water filtration, replenishment of groundwater sources and preservation of low vegetation have been distinctively disturbed by in turn rendering profound problems in agriculture. Water scarcity in dry season, high soil salinity and erosion are the most crucial problems emanating from the disturbance of the supported ecological services met in eastern Indian states (Shah, 2008). Although until recently the assessment of these services in agricultural water value was unusual, nowadays, they are acknowledged as indirect use values. They are however considered of equal significance with water use values (e.g. irrigation services) which are mostly identified as direct ones.

The paper attempts to identify the actual water value from irrigation and water related ecological services in representative backward clusters[1] of Bihar state in India. The direct water use values from irrigation services are disaggregated on surface and groundwater sources. Namely, the charges from canal irrigation, the capital, operational and maintenance expenditures from pumping and the shadow pricing from water trading are investigated. The indirect use value of ecological services is assessed through the environmental related problems on water quantity and quality status met in the examined districts.

For the assessment process, an extensive survey analysis in combination with secondary data is adopted. The survey is materialized through a household questionnaire form while the secondary data is originated from national authorities and sources from international organizations.

It should be mentioned that the research highly contemplates previous studies based on equilibrium analysis through demand and supply approaches (Krysiak and Krysiak, 2003; Xepapadeas, 2005; Kossioris et al, 2008; Phaneuf et al, 2008). Sound supply oriented econometric studies for water pricing through staple commodities in India have been also reviewed (Ranganathan and Palanisami, 2004; Kakumanu and Bauer, 2008). The introduction of user's preference approach for the demand assessment of irrigation in Indian cases is also apprehended (Kumar, 2001; Somanathan and Ravindranath, 2006; Kumar and Singh, 2005; Carson (Ed), 2007). The capturing of the total economic water value through relevant frameworks is another valuation approach that we share common research issues (Norberg, 1999; Faber et al, 2002; US EPA, 2002; Turner et al, 2004).

It should be noted however that the suggested approach does not follow a supply or demand oriented analysis neither does it offer an additional generic methodology for agricultural water valuation. It is instead accepted that the current canal charges linked with an administered price from governmental authorities, do encompass a direct water use value. Additional also direct use

[1] Cluster is considered to be a compound of small settlements which may be formed as villages or sparse inhabitants' areas.

values stemming from groundwater pumping costs and water purchasing costs are also identified. The indirect use value associated with related ecological services appears also to be a major determinant in agricultural water assessment (Bennet and Birol,2010). In this light, the analysis attempts to identify the actual water value corresponding to farmers in Eastern India from irrigation and related ecological services.

For a better correspondence of water value with farmers' economic status, a classification based on landholding size is conducted. By adopting the assumption that landholding size strongly pertains to farmers' wealth (CPWF, 2010), a classification between marginal, small, medium and large landholders is established. Emphasis is given to the water value attributed to marginal farmers.

**Methodological context**

The valuation of agricultural water preconditions a water economy scheme to be initially outlined. The prevalence of a resource base (aquatic ecosystem) together with the users and suppliers supervised by a regulatory mechanism are the essential components (Tsur, 2005). However, water valuation is not always perceived as a desirable action. Numerous ethical dilemmas are raised on the foothold that human beings are incapable of valuing s environmental related assets of which they are a part of (Limburg et al, 2002).

Nevertheless, water valuation concept is not based on the assessment of the entity per se. The entity's valuation is perceived through the intrinsic/inherent values acknowledged in an ecosystem and often remains a black box in valuation analysis (Brouwer et al, 1997). It is the instrumental value to be attributed in water related services (Spash, 2000). To this aim, the division between direct, indirect and non use values has been widely developed through a range of valuation guidelines and frameworks (Bateman and Willis 1999; Louviere et al 2000; Haab and McConnell, 2002; Champ et al, 2003; World Bank, 2004; Hensher et al, 2005). A representative example of economic valuation frameworks is depicted in Pearce (1993) as below:

Total economic value (TEV) = Use Values (Direct Use Value + Indirect Use Value) + Non Use Values (Option Values+ Existence Value)

Direct use values represent the services that are apparently linked with market commodities. The irrigation services or the sand extraction in a riverine ecosystem for instance, are directly distinct use values with a price tag. Direct use values with less distinctive association to markets as for instance flood or erosion avoidance are identified through shadow pricing from proxy or surrogate market commodities (US EPA, 2000). The indirect use values detect ecological services which somehow contribute to human welfare but are hardly quantifiable and matched with market products. Indicatively, natural water filtration in riverine ecosystem is an ecological process which could be theoretically assessed in economic terms through the mechanical filtration systems. However, such equivalence would undervalue the multiple benefits that simultaneously occur with the natural process such as fauna and flora improvement, microclimate stabilization and others.

The Non Use value category is of equal importance with Use values, but it exhibits intangible services provided by an environmental entity to human welfare. The prime category of Option values corresponds to a kind of deposit of ecological services for future use which could be perceived as an insurance premium for supply reserves (Atfield, 1998). Indicatively, the option value attributed to fishery stocks in a riverine ecosystem, could be rather high due to the assumption that a minimum viable population should be sustained for future fishing activities. The Existence value is interpreted as the instinctive desire of the individuals to preserve an ecological entity for aesthetical or intergenerational purposes.

The direct use vales emanating from irrigation services and the indirect values associated with ecological services are on the focus of this study. The economic values of irrigation are extracted from primary data through survey analysis for each water source type. Namely, the charges from canal water on a seasonal basis, the capital, operational & maintenance costs of pumping units and the costs of purchasing water through trading are assessed.

The ecological services are accordingly assessed through Willingness to Pay inference by open ended questions (Bateman and Willis, 1998). The biases of open ending approaches are taken into consideration as a threat to the distortion of the assessing outcome (NOOA, 1995). To this aim, an extensive introduction about the concept of economic assessment was offered by trained local researchers. The median value of the WTP was adopted due its relative steadiness in case of outliers (Garrod and Willis, 1999). The WTP related questions set in the assessment process are presented in Appendix 1.

For the estimation of the water value per unit of consumption or otherwise the marginal water use value, the capturing of the volumetric withdrawals should be accomplished. The respondents have noted the hourly water consumption of each crop type for different seasons. Based on this information, the equivalence of hourly consumption from canal water could be measured through secondary outflow data in a district level. However, for the case of pumping from groundwater the high heterogeneity of pump types could not be captured through secondary or primary data. Also, the rapidly expanded water trading derived by groundwater pumping is another major water source practice which could be hardly measured through actual data. In effect, a common practice mostly for marginal farmers with limited access to water sources is the purchasing of water on an hourly basis from farmers with private wells and pumps. Again, the high variation of pumping devices obstructed the gathering of information from the questionnaire or secondary sources.

To this aim, the water withdrawal was accounted according to the estimations of the net evapotranspiration for each cultivated crop in the examined districts. For a better clarification of the followed approach, the net evapotranspiration term is outlined. The evapotranspiration ($ET^p$) is a measurement of the amount of water required for plant growth. $ET^p$ measures the quantity of water transpired from plant tissues and evaporated from the surface of surrounding soil, expressed as a depth. $ET^p$ can be based on a number of factors including the local temperature, precipitation, cloud cover, solar radiation, and the type of plants cultivated in the examined area. The net $ET^p$ estimates the evapotranspiration after the deduction of the effective rainfall.

In our case, the data source for the monthly reference evapotranspiration ($ET^p$) and rainfall were provided by the Water and Climate Atlas data base created by International Water Management Institute (IWMI, 2010). In turn, the extracted monthly data was used to estimate the net evapotranspiration or the portion of consumptive water use (CWU) met from irrigation for the area of each cropping pattern as given from the survey.
The CWU required from irrigation for an $i^{th}$ crop in $j^{th}$ season is the difference between potential evaporation in four growth periods (initial, development, mid- and late stage) minus the effective rainfall. This is presented in equation (1) below:

$$CWU_{ij}^{IR} = A_{ij}^{IR} \times \left( \sum_{k \in growth\ periods} \left( Kc_{ijk} \times \sum_{l \in months} Et_{jkl}^{P} - \sum_{l \in months} ERF_{jkl} \right) \right) \qquad (1)$$

Where

$A_{ij}^{IR}$ = the irrigated area of the $i$ th crop (either rice, wheat, maize, other cereals, pulses, oilcrops, roots and tubers, vegetables, fruits, sugarcane, cotton or other crops) in the $j^{th}$ season (Kharif season (May to October) or Rabi season (November to April))

$Kc_{ijk}$ = the crop coefficients of $i^{th}$ crop in $k^{th}$ growth periods on the $j^{th}$ season

$Et_{jkl}^{P}$ = the monthly potential evapotranspiration amount of the $l^{th}$ month in the $k^{th}$

growth period in the jth season

$ERF_{jkl}$ = the effective rainfall of the $l^{th}$ month in the $k^{th}$ growth period in the jth

season

Thereafter, the marginal water use value for each source type is defined through the weighted average water charges stated by each farmer divided by the estimated corresponding CWU as below:

$$MWUV_{c,p,t}^{LMSM} = MV\{ (E[X_p]V_p / CWU_p), (E[X_m]V_m / CWU_m), (E[X_t]V_t / CWU_t) \} \quad (2)$$

Where

$MWUV_{c,p,t}^{LMSM}$ = Marginal Water Use Value on Canal ($c$), Pumping ($p$) and traded water ($t$) for Large, Medium, Small and Marginal farmers ($^{LMSM}$)
$MV$ = Marginal Value
$E[X]$ = Weighted Average
$V_p$ = the charges from public/canal water on seasonal basis
$V_m$ = the capital, operational & maintenance costs of pumping units
$V_t$ = the costs of purchasing water through trading
$CWU$ = Consumptive Water Use

For a more comprehensive assessment about the effects in farming community, the landholding size is introduced as a representative wealth related indicator. The sampling is classified in four landholding groups of large (>5ha), medium (2-5ha), small (1-2ha) and marginal farmers (<1ha).

Next, we explore the water dependence of farming groups to each water source type in an attempt to better address the valuation effects for each landholding group separately. In turn, we identify the median WTP for ecological services for each individual landholding group. However, the median WTP represents the yearly bid offered by respondents for the preservation of the ecological services. For the estimation of the marginal WTP per cubic meter on a yearly basis, the weighted average of WTP is examined in respect to the CWU on a landholding group wise order as below:

$$MWV_{es}^{LMSM} = E[X_{es}](WTP_{es} / CWU) \quad (3)$$

$MWV_{es}^{LMSM}$ =Water value for ecological services
$WTP_{es}$ = Willingness to Pay for ecological services like preservation of moisture, microclimate, avoidance of salinity, soil stabilization

The aggregation of equations 2 and 3 define the actual marginal water value reflected in irrigation and ecological related services for specific landholding groups in the cases examined.

**Case Analysis**

Bihar state situated in the eastern region of Ganges river in India was selected as a representative pilot case due to the abundant water recourses and diversified supplying types. On the other hand, low agricultural productivity, extreme poverty and regional disparities within the state constitute a highly contradictory profile. This is up to an extent justified by the highly fragmented landholdings and the extraordinary percentage of landless and marginal farmers (85% of population, Thorpe, 2007).

Also, the poor water control often results in the appearance of extreme events such as drought and floods but also in regular problems of not getting water to crops at appropriate times. Hence, the mismanagement of water supply is also to be heavily blamed for the deterioration of the rural livelihoods. The uneven land allocations and the poor water control mechanisms combined with high population density (880 persons/ sq. km), determine 43% of the population below the poverty line (BPL) (World Bank, 2005). Out of the 150 most disadvantaged districts in India, 15 districts are located in Bihar state.

The analysis attempted to shed light on the water value attributed to irrigation and ecological related services in selected backward districts of Bihar. For the accomplishment of the survey, 7 villages from the backward districts of Vaishali, Darbhanga, Munger and Patna were chosen as presented in the map below :

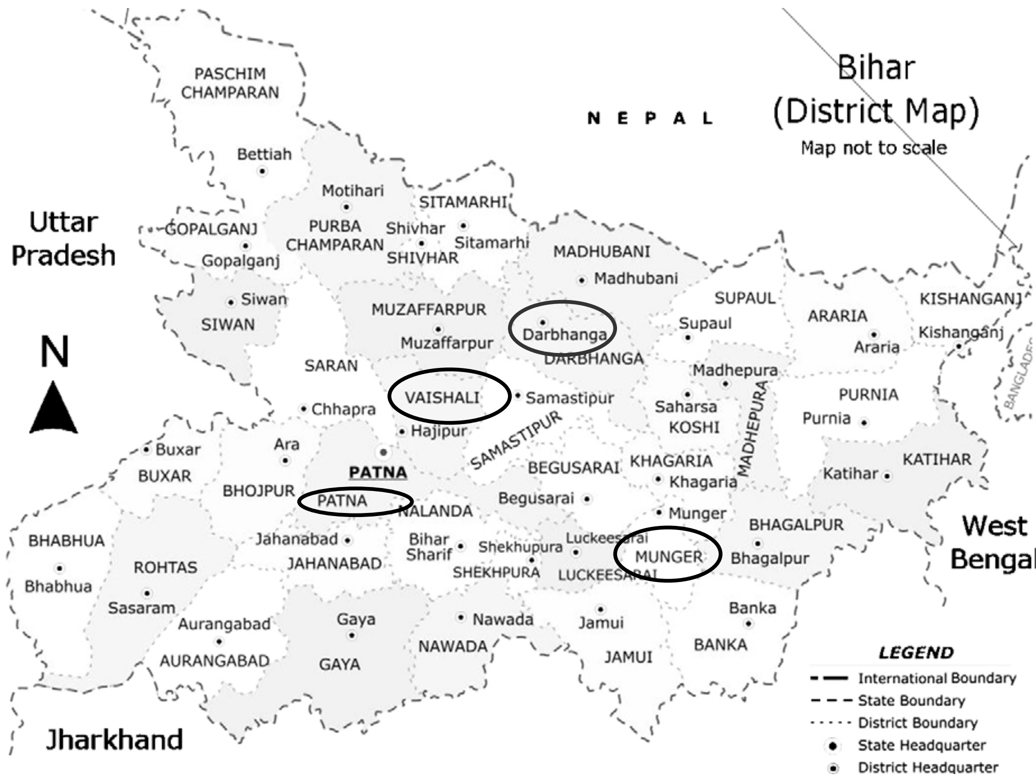


**Figure 1. Selected districts in Bihar state of Eastern India**

The selection of the clusters was based on a set of environmental, socioeconomic and technical criteria so as to attain the maximum possible diversification in the sampling size (Appendix 2). A random sample of about 30% of the total households was collected from each cluster resulting in a total of 489 responses as below:

**Table 1. Land and Farmers distribution in the survey**

| Districts | Clusters | Nos of Questionnaire |
|---|---|---|
| Vaishali | Chakramdas | 89 |
| | Pirapur | 115 |
| Darbhanga | Saramohanpur | 85 |
| Munger | Matadih | 50 |
| | Tikarampur | 50 |
| Patna | Rambad | 50 |
| | Hulsi-Tola | 50 |
| **Total** | **489** | |

The entire undertaking was held in cooperation with the Indian Council of Agricultural Research for Eastern Region (ICER/RCER) located at the capital of Bihar in Patna. The ICER/RCER drastically helped in the adjustment of the survey to the local peculiarities and to the appointment of local researchers. The survey was displayed and modified in a stepwise manner together with ICER/RCER partners through two workshops held in Patna at November 2008 and January 2009 where also the local researchers participated. A two rounds pre-testing was conducted in a village level as well to large, middle and marginal farmers respectively. The very remarkable results emerged by the two pretests, revealed the need to simplify the questionnaire particularly in the sections related the holding size and crop productivity. The entire undertaking lasted 9 months (November 2008 - August 20009) while the distribution and collection of the questionnaire was completed in 3 months. The local researchers where originated from nearby areas so as to ensure a familiarity with the customs and culture of the selected villages. The interviews were held on a face to face basis either in common reference buildings (e.g school, cooperatives etc.) or the in the houses of the interviewees. The on site interviews by local trained researchers eliminated the no response cases by almost attaining the target of 500 fully completed questionnaires.

The classification of the sample in the established landholding groups offered an insight about the land distribution and farmers' allocation in the surveyed areas. As noticed, more than half of respondents belong to marginal and small farmers who however possess only about 1/6 of the land examined in the sample area. . (Table 2).

**Table 2. Land and Farmers distribution in the survey**

| Landholding size (ha) | Land distribution (ha) | Farmers (%) | Land Area (%) |
|---|---|---|---|
| **0-1 (marginal)** | 56.5 | 29.8 | 5.3 |
| **1-2 (small)** | 124.1 | 24.5 | 11.7 |
| **2-5 (medium)** | 297.7 | 28.6 | 28.2 |
| **5-50 (large)** | 574.3 | 17.1 | 54.8 |
| **Total** | 1052.6 | 100 | 100 |

A reverse situation is figured in the case of large farmers with land possession of more than half of the total area but representation of about 1/6 of the sample. The highly unequal land distribution confirms the theoretical speculation of land accumulation from large owners in agricultural dependent regions of developing countries (Khandker and Haughton, 2010).

For the assessment of the marginal water value, the estimates of net evapotranspiration (the difference between the potential evapotranspiration minus effective rainfall) for the examined districts are identified. In the case of paddy cultivation, a 200 millimeters (mm) for percolation requirements is added (Table 3).

**Table 3. Net evapotranspiration in selected districts of Eastern India (in mm).**

| Districts | Vaishali | | | Munger | | | Darbhanga | | | Patna | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Crop/Season** | **K** | **R** | **A** | **K** | **R** | **A** | **K** | **R** | **A** | **K** | **R** | **A** |
| **Paddy** | 159 | 615 | | 108 | 597 | | 129 | 540 | | 167 | 633 | |
| **Wheat** | | 278 | | | 291 | | | 260 | | | 285 | |
| **Maize** | | 249 | | | 260 | | | 232 | | | 255 | |
| **Oth.Cereals** | | 213 | | | 225 | | | 200 | | | 219 | |
| **Pulses** | | 179 | | | 189 | | | 170 | | | 184 | |
| **Oil Crops** | | 197 | | | 210 | | | 186 | | | 203 | |
| **Vegetables** | 71 | 343 | | 25 | 354 | | 47 | 318 | | 77 | 352 | |
| **Fruit** | | | 369 | | | 332 | | | 317 | | | 385 |
| **Sugar** | | | 755 | | | 704 | | | 669 | | | 777 |
| **Cotton** | | | 156 | | | 142 | | | 142 | | | 165 |
| **Fodder** | 74 | 282 | | 26 | 296 | | 48 | 267 | | 80 | 289 | |

*Note : K = Kharif season (May to October), R= Rabi season (November to April), A= Annual*

***Source:*** *Authors estimates based on the climate data from IWMI Water and Climate Atlas, 2010*

In turn, the marginal water use value for each source type is explored. The findings reveal a high value difference in pumping water between large farmers and other landholders (Table 4). This is mainly to be justified by the capital costs for drilling works, pump purchasing and high operational and maintenance costs in case of diesel pumps (Amarasinghe et al, 2007a). However, at the same time marginal farmers are also called to pay an even higher value for the traded water. By considering that the study accounts only the purchased traded water without assessing the benefit from water selling practices, it appears that the condition of communicating vessels between large and marginal farmers occurs. Large farmers bear the high costs of pumping water by however transferring the burden to the marginal landholders through the unofficial traded schemes. The earnings from water selling by large farmers are internalized in their income and hence they are not assessed again in the analysis due to double counting effects.

**Table 4. Weighted average water charges for each source type (in US$)**

| Landholders | Pumping [$/m3] | Canal [$/m3] | Traded [$/m3] |
|---|---|---|---|
| **Marginal** | 0.010 | 0.012 | 0.023 |
| **Small** | 0.011 | ----- | 0.012 |
| **Medium** | 0.013 | ----- | 0.013 |
| **Large** | 0.021 | 0.011 | 0.013 |

To this end, marginal farmers are requested to afford about twice the price for purchased water while for the rest three groups the cost is almost equal. More, marginal farmers appear to expend the higher amount for canal water than large landholders while there is no data for medium and smaller ones.

The burden of the traded water value for marginal farmers could be better conceived through a water source dependence overview. As presented in Table 5, more than 2/3 of the marginal farmers rely on water purchasing while the amount fall into 1/3 for the case of large landholders. On the contrary, almost half of large farmers own pumping devices mostly for groundwater extraction while the amount of marginal farmers with pumping devices is negligible.

**Table 5. Water source dependence**

| Water Sources | All landholding groups (%) | Marginal Farmers (%) | Large Farmers(%) |
|---|---|---|---|
| **Canal Water(public)** | 11.85 | 13.64 | 8.33 |
| **Pumping (private)** | 23.22 | 6.82 | 45 |
| **Water Buying** | 54.93 | 77.27 | 31.67 |
| **Pumping (priv.)& buying** | 9 | 2.27 | 15 |
| **Total (%)** | 100 | 100 | 100 |

The low coverage and unreliability of canal irrigation together with the high capital and operational costs of pumping systems seems to force low incomes into water purchasing. For the case of canal water, the dependence of both large and marginal landholders is almost equally low which is also reflected in the case of all landholding groups.

The large dependence of marginal farmers on highly charged traded water results in the boosting of the overall marginal water use value for the three water source types (canal, pumping, trading). Marginal farmers appear to get charged almost twice the value of the small and medium ones while a distinctive difference among large farmers is portrayed (Table 6).

When assessing the median WTP for ecological services it is clearly depicted the strong willingness of large farmers to finance the resolution of water related environmental problems. Noteworthy is the almost equal contribution of marginal farmers with the small and medium groups despite the considerable income differentiation. In an attempt to portray WTP on marginal basis, we account the WTP for each landholding group in respect to the estimated CWU for all irrigated areas of each farmer. It is then exhibited that because marginal farmers consume nominal water, the WTP per cubic meter becomes the highest amongst all other groups. Contradictorily, in the case of large landholders the manifold water consumption in comparison to marginal group distinctively lowers the marginal WTP into half .

**Table 6. Marginal Water Value for irrigation and ecological related services**

| Landholders | M. Wat.V. [$/m3] | WTP ($/year) | Est.CWU (m3/yr) | M. WTP [$/m3/CWU] | M.Wat.V.(irr.+ ec.) [$/m3] | Diff.(%) |
|---|---|---|---|---|---|---|
| **Marginal** | 0.021 | 3.13 | 665 | 0.0026 | 0.0238 | 118 |
| **Small** | 0.011 | 3 | 2,950 | 0.0012 | 0.0129 | 18 |
| **Medium** | 0.010 | 4 | 5,654 | 0.0008 | 0.0109 | ------- |
| **Large** | 0.017 | 18.45 | 16,988 | 0.0013 | 0.0189 | 73 |

***Note****: M. Water Value: Marginal Water Value for irrigation, Est. CWU: Estimated Consumptive Water Use, M. WTP: Marginal Willingness to Pay, M.Wat.V.(irr+ec.)=: Marginal Water Value of Irrigation and Ecological related services, Diff (%): Difference among the value attributed to medium and the other landholding groups*

This observation is not theoretically validated by relevant guidelines where standard deviation indicator usually signposts the dispersion of the WTP bids (Bann, 1997; Brouwer et al, 1997). However, it could comprise a consistent indicator of the highly notable willingness of marginal farmers to factually participate in the conservation of ecological services.

The sum up of the values from irrigation and ecological services, reveals the highest marginal water use value to distinctively correspond to marginal farmers. An about twofold difference is observed amongst the marginal and medium together with small farmers where in the case of large farmers the difference is decreased in half.

## Discussion

The valuation of the direct and indirect water use of irrigation and ecological related services followed some presumptions. Initially, the estimation of the net evapotranspiration might have deviated from the actual water use conditions met in each single case of the sampled area. The plethora of water supply systems might attribute different actual water consumptive use than the estimated ones. In that case, the dependence of cropping patters on the actual water sources and land size might varies from our estimations in the four examined districts. However, the measurement of the actual data was hindered by the high heterogeneity of pumping devices and broadly the extraction devices met in groundwater sources. Hence, the valuation of irrigation services through an approximate volumetric outflow of groundwater sources would possibly entail in much higher divergence from our estimations. Thus, the estimated net evapotranspiration approach was selected instead.

Second, the research assessed the marginal value of specific water uses, namely the direct use value from irrigation and the indirect from ecological related services. The marginal value from irrigation services stems from the actual costs for water supply per cubic meter of water. The research assumes that the actual water supply costs should be reflected in an efficient pricing mechanism set by irrigation authorities which accordingly should reveal the marginal value for irrigation services.

Third, the water value attributed to ecological related services is known to be alternatively captured through cost replacement methods and supply side approaches. In that case, the costs required for the remediation of the disturbed ecological services mainly through mechanical interventions should reflect the value of these services (Carson, 2007). However, these methods often underestimate the contribution of ecological services to agriculture and they totally ignore users' (farmers') potential economic contribution for the restoration of these services. To this aim, a demand side approach was selected based on the WTP inference to reveal the actual farmer's condescension in the preservation of ecological services.

The study findings present an exclusive almost dependence of marginal farmers to water purchasing which mostly derives from groundwater pumping. Still however, the bulk of irrigation investments in Bihar state are spent on canal irrigation for sufficient production but also for ensuring livelihood security to subsistence farmers. According to Central Water Commission of India (2008), 118m US$ were invested on average per annum for the years 1995-2003 in irrigation projects to Bihar state. The vast majority of the investments are driven towards large and medium canal irrigation projects.

Currently, the extremely low investing returns (0.19%) of the irrigation expenditures in Bihar do not justify the invested amounts. All the more, the recovery indicator accounts only for working expenses since the capital outlay is acknowledged to prevalently promote infrastructural purposes.

In case a redesigned pricing policy would be planned towards more efficient canal irrigation, then the weakest farming group to potentially benefit from a change should be considered. A potential scenario with the data findings of the four disadvantaged districts could be elaborated. In case large farmers would be requested to pay higher charges for revenues improvement and transfer payment to marginal farmers, low effects are anticipated to occur. The negligible proportion of large landholders (8.33%) that is currently supplied from canal irrigation would possibly decrease in the hearing of higher canal charges. Additionally, the benefits to marginal farmers from heavier subsidization by transfer payments would be also rather low. Bearing in mind that currently only 13.64% of marginal farmers use canal irrigation through a nominal pricing policy it is questionable whether an even free of charge supply scheme would be more attractive.

In the case of ecological services, the median WTP findings reaffirm the theoretical background about the proportional increase of WTP in respect to welfare status (Bennet and Birol, 2010). However, when estimating marginal WTP per cubic meter, it seems that results are partly in discrepancy with theory. Marginal farmers appear to offer twofold WTP bids from small and medium farmers by also taking the lead from large landholders.It is still questionable though whether the agreeable stance stems from their awareness on environmental issues or the conceiving of the proposed assumptions as mere hypothetical scenarios.

## Conclusions

The highly unequal land distribution depicts a de facto difficulty of marginal farmers to implement large-scale irrigation systems and reduce water costs. The comprehensive description taken in our study on the allocation of water charges in regard to source types, reaffirms the heavy burden undertaken by marginal farmers. The water pumping charges which initially seem to designate large farmers as the evident water value undertakers are completely offset by the higher water trading charges attributed to marginal farmers. This cost shifting portrays marginal farmers to get aggravated with the highest charges for irrigation services. The situation seems unlikely to reverse since marginal landholders can hardly receive financial aid for groundwater facilities under the current irrigation policy.

The highest water value signaled to marginal farmers is further confirmed through their leading contribution inferred by the apportionment of WTP with the estimated water consumptive trends (CWU). However, this experimental distribution should be validated through similar research findings. Overall, the affirmative stance of all the landholding groups indicates that a potential inclusion of environmental charges would not meet stiff resistance from users.

The structural deficiencies of the current irrigation policy seem to be blamed for the actual manifold water value corresponding to each landholding group and the disproportionate effects to marginal farmers. Specifically, the poor maintenance of canal networks highly discourage most of the farmers to make use of canal irrigation. The reorientation from canal to groundwater irrigation projects with subsidization of marginal farmers could reverse the current trends and lead to efficient pathways (Shah et al, 2009). However, the subsidization of groundwater project would not avail alone, unless some also complementary measures would be adopted. A promising initiative could be the replacement of hydrophilic staple crops with more water resistance cropping patterns. Recent introduction of diversified cropping patterns in the examined districts gives an insight of alternative successful cultivation with high economic potential (Amarasinghe et al, 2007b). The level of reformulation and the synergies emerged from a simultaneous change are subject to an in depth research and out of the scope of the paper. However, the supervision of underground irrigation systems through institutional settings and regulatory mechanisms are anticipated to be essential organizational components (Shah, 2008).

The appropriateness of the analysis to real case situations was tested and appraised in representative backward clusters of Bihar state in Eastern India. The generalization of the research findings to other Indian or South Asian resembling cases could probably lead to misleading assumptions. However, the cautious transfer of the suggested valuation approach in similar cases met in South Asia could aid towards a more efficient and equitable irrigation policy.

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**Appendix 1. WTP Questions for Environmental Services**

<table>
<tr><td colspan="4">1 Nowadays, there is no cost for the water as a good but only for pumping and distribution services. If the government would ask for a charge in order to preserve the environmental services provided by freshwater, like preservation of moisture, microclimate, avoidance of salinity etc. would you be willing to financially contribute for its preservation?</td></tr>
<tr><td>Yes (Go to Q.1.1)</td><td>Depends on the amount asked(Go to Q.1.1)</td><td>No (see below)</td><td></td></tr>
<tr><td colspan="4">IF ''NO'' Why : I am opposed to such economic approaches =1, I do not trust the payment authority =2, I do not have enough money to pay =3, I believe that it is not me to pay for these services =4</td></tr>
<tr><td colspan="2">IF ''YES'' 1.1 What is the maximum amount you could contribute per year? (Mention to the farmer that the amount is per year only)</td><td colspan="2">Maximum amount Rs/ Year<br>_______________</td></tr>
</table>

**Appendix 2. Criteria for the selection of a representative clusters Bihar state**

<table>
<tr><td rowspan="6">Agro-ecological sub-region (iternation al indexes)</td><td rowspan="6">Soil type (international indexes)</td><td>Agricultural water patterns</td><td>Cultivation seasons</td><td>Environmental characteristics</td></tr>
<tr><td>Tube well</td><td rowspan="2">Kharif (rainy)</td><td>Near to river</td></tr>
<tr><td>Bore well</td><td>Near to spring</td></tr>
<tr><td>Canal</td><td rowspan="2">Rabi (winter)</td><td>Near to forest</td></tr>
<tr><td>Pond/tank</td><td>Water congested area</td></tr>
</table>

*Notes: Kharif season: May to October; Rabi season: November to April*