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**RESEARCH
INTERESTS**

- Water Management and Drainage in Agriculture
- Groundwater Management
- Forest Use in Developing Economies
- Groundwater Quality Externalities

**TEACHING
INTERESTS**

- Natural Resource Economics
- Environmental Economics
- Microeconomics
- Econometrics
- Macroeconomics

DEGREES

- Doctor of Philosophy in Economics, University of California, Riverside, August 2008
Dissertation: *Microeconomics of Water Management: Spatial Dynamics and Sustainability*
Committee: Prof. Linda Fernandez, Prof. Keith Knapp (Chair), Prof. Kurt Schwabe, Prof. Aman Ullah
- Master of Arts in Economics, Gokhale Institute of Politics and Economics, Pune, India, June 2000
- Bachelor of Arts, The Ethiraj College for Women, University of Madras, Chennai, India, June 1998

AWARDS

- *Best Poster Presentation in Economics*, Graduate Student Association Annual Research Conference, University of California, Riverside, June 2008
- *Reader of the Year*, Department of Economics, University of California, Riverside, 2007 – 2008
- *Outstanding Teaching Assistant*, Department of Economics, University of California, Riverside, 2005 – 2006
- *Phi Beta Kappa International Scholarship Award*, Alpha Association of the Phi Beta Kappa Alumni in Southern California, 2005 – 2006
- *Chancellor's Distinguished Fellowship Award*, Department of Economics, University of California, Riverside, 2001 – 2005
- *V. L. Ethiraj Scholarship*, The Ethiraj College for Women, Chennai, India, 1997 – 1998
- *Dharmaprakasa Lokkur S. Venkaji Rao Medal*, First in B. A. Economics in The Ethiraj College for Women, Chennai, India, 1995 – 1998
- *Seventh Rank in Economics*, University of Madras, 1995 – 1998

- EMPLOYMENT EXPERIENCE
- Department of Economics, The Robert Day School of Economics and Finance, Claremont McKenna College
Visiting Assistant Professor Fall 2008
Principles of Economics
 - Department of Economics, University of California, Riverside
Associate-In
International Finance Summer 2004
Introduction to Environmental Economics Summer 2006
Macroeconomic Theory II Summer 2008
Lecturer
Introduction to Money, Banking, and Credit Fall 2008
Reader
Trade, Globalization, and Development Winter 2008
Macroeconomic Theory II Summer 2003
Teaching Assistant Fall 2001 – Spring 2008
Introduction to Economics
Introduction to Microeconomics
Introduction to Macroeconomics
Introduction to Environmental Economics
Introductory Econometrics I
Research Methods in Business and Economics
Microeconomic Theory I
Macroeconomic Theory I
Macroeconomic Theory II
Natural Resource Economics
 - Department of Environmental Sciences, University of California, Riverside
Research Assistant to Prof. Keith Knapp Spring 2005 – Fall 2008
 - Gokhale Institute of Politics and Economics, Pune, India
Research Assistant to Prof. Vikas Chitre Summer 2000
- PUBLICATION
- “Judicial Reforms, Development, and India,” in *Essays in Development Economics*, ed. Ira Athale, *Gokhale Institute Students’ Publication Series No. 1*, Gokhale Institute of Politics and Economics, Pune, India, August 2000, pp 10 – 16.
- MANUSCRIPT UNDER REVIEW
- “Spatial Dynamics of Water Management in Irrigated Agriculture,” joint with Keith Knapp, revised and resubmitted to *Water Resources Research*, August 2008.

WORK IN
PROGRESS

- “Comparison of Optimal Control and Common Property in Groundwater Use Decisions in Kern County,” joint with Keith Knapp, March 2008.
- “Competition and Optimal Control in Seawater Intruded Aquifers,” September 2007.
- “Impact of Access to Credit on Forest Resource Use by the *Orang Asli* in Peninsular Malaysia,” joint with Kurt Schwabe, February 2008.
- “Sustainability and Groundwater Resources,” joint with Keith Knapp, July 2008.

PROFESSIONAL
MEETINGS

- “Spatial Dynamics of Water Management in Irrigated Agriculture,” poster presented at the Graduate Student Association Annual Research Conference, Riverside, California, June 8 2008
- “Spatial Dynamics of Water Management in Irrigated Agriculture,” poster presented at the First Western Forum on Energy and Water Sustainability, Santa Barbara, California, March 22–23, 2007
- “Spatial Dynamics of Water Management in Irrigated Agriculture,” presented at the Ninth Occasional Workshop in Environmental and Resource Economics, Santa Barbara, California, November 3–4, 2006
- “Spatial Dynamics of Water Management in Irrigated Agriculture,” presented at the Economic Theory Colloquium, Department of Economics, University of California, Riverside, California, October 23, 2006

PROFESSIONAL
AFFILIATIONS

- Agricultural and Applied Economics Association
- American Economic Association
- Association of Environmental and Resource Economists
- Western Agricultural Economics Association

REFERENCES

- Linda Fernandez, Associate Professor, Department of Environmental Sciences, University of California, Riverside, CA 92521
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Research Summary

The ability of a dwindling natural resource base to meet society's ever-increasing demand has received much attention in the field of natural resource and environmental economics. Many if not most resources can provide a variety of services to society, and hence a better understanding of the value of each sort of service becomes imperative if one is concerned with efficient use of such resources. For instance, groundwater can be as a drinking water source or as an input into irrigated agricultural production; forest resources can be used as an input into pulp and paper production, or a source of income and livelihood for poor forest fringe communities. As most natural resources fall into the category of common property resources, the ability of the market, when left to its own devices, to allocate these resources to their highest valued uses is limited. This market failure is particularly compounded in developing countries, where poor resource management can have very deleterious effects on the standard of living of local populations. The optimal use of these resources also raises questions about inter-generational equity since current resource usage inevitably impacts future availabilities, if not in quantity then surely in quality. My research contributes to the growing body of literature that addresses these issues.

A. Microeconomics of Water Management: Spatial Dynamics and Sustainability

My dissertation comprises four core essays. A brief description of each follows:

Essay 1: Spatial Dynamics of Water Management in Irrigated Agriculture

Irrigated agriculture provides 40% of worldwide food supplies, but uses large amounts of scarce freshwater supplies and contributes to environmental degradation (nutrients, pesticides and salinity). At the very core of this problem lie decisions made by irrigators subject to biophysical relations. This research develops a microeconomic model of irrigation management taking into account the dynamics of plant growth over the season, spatial variability, and fundamental principles from subsurface hydrology. The production function is defined implicitly as a daily model of plant growth over the season. Non-uniformity (spatial variability) is introduced by assuming a lognormal spatial density function for water infiltration integrated over the field. Optimal water applications are obtained by maximizing profits subject to the various constraints.

The empirical component of the study uses cotton as the target crop. In general, the analysis

shows that introducing spatial variability common to traditional irrigation systems increases applied irrigation water by 30% or more over profit-maximizing levels if spatial variability is ignored. Likewise, deep percolation flows are also greatly increased over the uniform case. As these flows contain pesticides, nutrients, and salts, accurately accounting for spatial variability becomes fundamental for both understanding how natural resource and environmental problems arise in irrigated agriculture as well as predicting grower response to various regulatory policies. The analysis is conducted using GAMS/CONOPT nonlinear optimization procedure for cotton production in and finds relatively small costs in reducing deep percolation flows up to a certain level. Irrigation systems differ with respect to uniformity of water application. Changes in water use and profits are examined for different irrigation systems. More uniform systems result in lower water applications and deep percolation flows. Most economic analysis focuses on fallowing land, changing crops, or changing irrigation technology to conserve water. However, the results of this analysis suggest that better water management at the field-level would enable water conservation to a large extent, and we find that in the long-run – for the crop considered here – capital-intensive irrigation systems are efficient only for quite high water prices.

Essay 2: Groundwater Economics and Management

Groundwater comprises approximately 20% of the world's freshwater withdrawals, while in the United States it contributes to 42% of the water used in irrigation. The goal of this research is to compare common property and optimal control decisions for groundwater use in order to achieve sustainable use and management of groundwater resources. The benefits from groundwater use come from agricultural production. Parameters are obtained using Kern County data and the model is solved using GAMS/CONOPT nonlinear optimization procedure. The model incorporates multiple crops and irrigation systems. The analysis evaluates the impacts of surface water cutbacks and changing energy prices on source control decisions (e.g., irrigation system choice, applied water rates, crop mix), and the impacts on groundwater quantity.

The analysis finds that the common property solution has higher groundwater withdrawals in the initial years and leaves the water table at steady-state at a much lower level than when there is management. Surface water cutbacks have an effect on the common property solution only for cutbacks higher than 30%. The water table is lowered at a faster rate in the initial years. The steady-state is the same for all situations. In the efficient solution, although the

water table height falls with surface water cutbacks, it is consistently higher than the common property case. These results suggest that the benefits from management when there are surface water cutbacks fall with an increase in cutback. This could be attributed to increases in cost of water applications and reduction in yield due to lower applications of water.

Changes in energy prices have a positive impact on hydraulic head in the case of common property and efficiency solution. Groundwater withdrawal is lower, higher the price of energy. In the case of rising energy prices, the analysis here finds that, contrary to the Gisser-Sanchez paradox, management does have significant benefits when facing a situation of rising profits.

Essay 3: Sustainability and Groundwater Resources

Groundwater availability has had a significant effect on irrigated agriculture since it allows for timely irrigation and security of application. The current situations of food and water scarcity bring issues of sustainable groundwater management to the forefront. From an economic perspective, issues of sustainability focus on the trade-off between current and future consumption. However, technological innovation ensures a substitution of created capital for natural capital that needs to be accounted for when evaluating sustainability of a natural resource.

The regional groundwater model is extended to incorporate an asset accumulation model in order to account for sustainability. The present value of welfare is maximized for the farmer, where the farmer's consumption depends on income from agriculture (that depends in turn on groundwater use) and savings. The model is considered with an application to Kern County and solved using GAMS/CONOPT nonlinear optimization procedure. Consumption is found to be non-declining over time. The results show that the water table height after including the asset accumulation model is higher than the common property solution but is the same as the management solution. Although income from agricultural production is falling, consumption is maintained at the same level from the savings from past earnings.

Essay 4: Seawater Intrusion in Coastal Aquifers (A Theoretical Exposition)

Groundwater is well recognized as a common property resource. The problem of externalities associated with any common property resource also applies in the case of groundwater exploitation. Therefore, we find optimal control solutions that account for the externalities. Some of the externalities considered in groundwater economics literature include pumping externalities, stock exhaustion, and risk externalities. Other externalities like land subsidence and groundwater quality externalities, like seawater intrusion in coastal aquifers, have received scant attention in the literature. This essay focuses on developing a theoretical model that accounts for the effects of seawater intrusion on groundwater pumping.

The model described here presents a more accurate representation of the seawater intrusion externality than is seen in the literature. The nonlinear nature of the relationship between the externality and pumping influences the solution, and hence policy. By considering hydrologically-linked aquifers, heterogeneity and variability is introduced in the model. The introduction of the salt balance equation gives a more realistic and accurate picture of the differences between the competitive and optimum solution.

This model presents a co-evolution of the social and hydrologic problem. The quantity and quality aspects of groundwater extraction are considered simultaneously, and it is expected that the benefits from management will be greater in this case. If the benefits from management are greater, then the need for policy intervention is reinforced. The alternative policy regimes to be considered depend on what would be most effective in the particular region of study, and the comparative welfare loss.

B. Forest Use in Developing Economies

It is estimated that nearly 80% of the developing world relies on non-timber forest products (NTFPs) for nutritional, health, and income needs. This includes about 60 million indigenous people who rely on forest resources as a form of alternate livelihood. For those who rely on forest resources in this manner, many alternate sources of reducing risk and smoothing consumption, including access to credit, are not readily available.

Relationship between credit and NTFP collection for the Jah Hut community in Peninsular Malaysia

This paper examines how access to credit impacts natural resource use among 259 Orang Asli households from the Jah Hut community living on the margin of the Krau Forest Reserve in Peninsular Malaysia. A two-stage switching regression model is used in the analysis. In the first stage, a probit regression model is used to determine the factors that influence a household's (unobservable) excess demand for credit. In the second stage, we use separate regression equations to model NTFP collection decision of the two groups of households (credit constrained and non-constrained). The Inverse Mills Ratio is obtained from the first stage probit regressions and used in the second stage regressions to correct for any potential sample selection bias.