



lands for pump-irrigation schemes. The goal is to extract available river water to irrigate a dry season crop. The harvests of two annual crops in the wetlands holds hope for increasing production of rice, the regional dietary staple. Some 10,000 acres (4,000 hectares) of wetlands now are developed to irrigation projects out of an estimated 60,000 acres (24,000 hectares) farmed with traditional swamp rice methods.

However, the irrigation technology has largely failed to create a sustainable form of agriculture. In part this is because the high price of diesel has made the operation of irrigation pumps extremely costly in a society where the average per capita income hovers around \$450 annually. This also affects the price of fertilizer. The most productive rice varieties demand significant amounts of fertilizer, and in just 20 years its price has quadrupled. Fertilizers are now priced beyond the means of most rural producers. Inappropriate technology transfer also occurred amid misguided attempts of development planners to attract Gambian men to rice cultivation. They awarded the developed irrigated plots to women's husbands rather than to the traditional female growers. As a consequence, women became laborers on the very fields they previously managed and used for income generation. Conflict between men and women erupted frequently in the implementation of pump-irrigation schemes.

Fortunately, many lessons have been learned. Technologically sophisticated irrigation systems similar to those in California are not feasible for cash-strapped rural populations. New approaches to raising African food production now center on building upon the ecological knowledge already held by rural people in farming diverse environments. One of the crucial lessons of Gambian wetland development is the significance of women's work and environmental knowledge for raising food production. Any project that aims to improve food availability in rural West Africa now assumes that men and women often work separately, with different crops, and frequently in dissimilar environments.

The Gambia River still defines the country and its people. A river that flows through parched landscapes is being once more returned to its custodians, the female rice growers. Development assistance now helps them level the floodplains in order to restore

the river's natural reach. In improving its tidal reach, the river now flows unimpeded across women's rice fields, as it seeks its outlet to the Atlantic.

SEE ALSO: Drought; Floodplains; Irrigation; Maize; Poverty; Rice; Riparian Areas; Wetlands.

BIBLIOGRAPHY. Alex Haley, *Roots: The Saga of an American Family* (Doubleday, 1976); Margaret Haswell, *The Nature of Poverty* (St. Martin's Press, 1975); Richard Peet and Michael Watts, eds., *Liberation Ecologies: Environment, Development, Social Movements* (Routledge, 2004); Richard Schroeder, *Shady Practices: Agroforestry and Gender Politics in The Gambia* (University of California Press, 1999); Donald R. Wright, *The World and a Very Small Place in Africa* (M.E. Sharp, 2004).

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## Game Theory

GAME THEORY IS the application of applied mathematics and evolutionary theory to understanding people's strategies in maximizing benefits. Game theory began as a system for understanding card games with its first practical application to economics in the early 20th century. Several human behavioral sciences (psychology, sociology, and anthropology) use game theory to understand why individuals may be in conflict or cooperation given specific situations.

The two main representations of game theory are *normal*, which is sometimes referred to as *strategic*, and *extensive form* games. In the normal form game, each player has two strategies—cooperate or defect. If player one defects and player two cooperates, the defecting player's payoff (reward) is higher (e.g., \$6) than the player who cooperates (e.g., \$0). If both player one and two cooperate, they receive an equal payoff (e.g., \$3). If both player one and two defect, they receive an equal payoff (e.g., \$0). The players do not know what the others' actions will be before they make their own choice, thereby limiting their ability to cooperate by prior agreement with each other. Each play does not connect to the next.



The extensive form game is structurally similar to a normal form game, but instead tracks player choices over time, thereby enabling the assessment of more complex decision-making strategies. Extensive form games also enable players to make decisions based upon what choice the other player has made. For example, if one player decides to cooperate, the second player may then decide to cooperate (both players' payoff is \$3) or defect (player two's payoff is \$6 and player one's, \$0). In addition, if both defect, they both receive no payoff. Since players make decisions based on previous choices, extensive form games make use of diagrams, often tree diagrams, to represent the order and outcomes of choices over time.

There are several variations of the normal and extensive form games. In a symmetric game variation, the payoffs are the same for both players. In an asymmetric game variation, the payoffs are different for each player and the strategy for each player to do well in the game is different. A game may be zero sum, in that the result of the game always equals zero because when one player has a positive payoff, the other takes a negative payoff. To explore the impact of games on decision making, one may also change the length of the game, number of players, and strategies available to the players.

In environmental anthropology, game theory has been widely used in studies of the Tragedy of the Commons. Robert Axelrod applied the normal form game—the prisoner's dilemma—to the Tragedy of the Commons. Axelrod and others are concerned with the problem of explaining why and how cooperation evolved without central authority. By being able to explain the evolution of cooperation, it can be determined how much, and in what capacity, cooperation may avert the Tragedy of the Commons. With this knowledge, viable solutions relying on realistic expectations of cooperation should result in conservation of common resources.

As important as explaining the evolution of cooperation is to commons management, what is essential is an understanding of how to maintain cooperation in a community, because only through such understanding can a program succeed. The stability of a cooperative strategy, as understood within a prisoner's dilemma game, depends on the ability of a dominant strategy to resist invasion by a free-riding strategy.

SEE ALSO: Prisoner's Dilemma; Tragedy of the Commons.

BIBLIOGRAPHY. Robert Axelrod, *The Complexity of Cooperation: Agent-Based Models of Competition and Collaboration* (Princeton University Press, 1997); Robert Axelrod, *The Evolution of Cooperation* (BasicBooks, 1984); Drew Fudenberg and Jean Tirole, *Game Theory* (MIT Press, 1991); John Maynard Smith, *Evolution and the Theory of Games* (Cambridge University Press, 1982).

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## Ganges River

THE GANGES RIVER, 1,557 miles in length, flows eastward along the border separating the Himalayan complex and the flat expanse of the Indian subcontinent. Known to Hindus as the *Ganga*, the river is a source of water for human consumption, agriculture, and industry. The Ganges is worshipped in the Hindu religion as a goddess. People bathe in the waters of the Ganges to be cleansed of sins and to ensure salvation. It is believed that drinking water from the river with one's final breath will deliver the soul to heaven. The number of people living along the broad Ganges river valley approaches 300 million. The Ganges is perhaps the most polluted river on the planet. The volume of raw sewage spilled into the river is gigantic. In addition, a variety of industrial wastes find their way into the river. One in particular is especially damaging: the leather industry located near Kanpur emits large amounts of chromium into the river.

The Ganges Action Plan, initiated in 1985, was established to address serious pollution problems along the river. The program includes the building of a number of solid waste treatment plants along the river in an attempt to reduce the enormous amounts of sewage absorbed in the water. Hindu politicians have traditionally not been very active in support of the plan. Some environmentalists believe that progress is being made on this program. However, the enormity of the situation will require an energetic and sustained effort well into the future