Tree and Forestry Science and Biotechnology ©2009 Global Science Books

Economics of Variable Rate Nitrogen Application in Florida Citrus Grove

Ganesh C. Bora*

Agricultural and Biosystems Engineering Department, North Dakota State University, P.O. Box 6050, Fargo, North Dakota 58108, USA

Correspondence: * **ganesh.bora@ndsu.edu; ganeshbora@yahoo.com**

ABSTRACT

Precision farming is a management system to optimize input and maximize benefits. Variable rate technology (VRT) of inputs is an important component of precision agriculture that results in the reduction of inputs. This not only provides economic benefits to the farmers along with reductions in agrochemicals and fertilizer application, but also has positive environmental impact. Citrus growers in Florida are willing to adapt VRT fertilization, if they are aware of the economic benefits. This study attempted to estimate the economic benefit of VRT fertilization by accounting the savings of amount of fertilizer. There is a potential of 40% savings of urea which corresponds to US$138/ha/year. Although the initial investment for a VRT spreader is high, to the tune of twenty nine thousand dollars, its use for 558 ha of citrus grove would pay for it considering even 15% reduction in amount of urea applied. Assuming a 40% reduction in urea and about 40% adaptation rate VRT fertilization, there is a potential of savings of 8.3 million kg of urea and US$10.7 million per year in Florida. This would also marginalize the gap between demand and supply; reduce nitrate leaching and fertilizer uptake efficiency.

Keywords: economic benefits, fertilizer application, precision agriculture, variable rate technology
Abbreviations: SSM, site specific management; **URT**, uniform rate technology; **VRT**, variable rate Technology

CONTENTS

INTRODUCTION

Precision agricultural technology is fast emerging as an aid to the farming community by improving production efficiency, optimizing inputs, reducing environmental pollution by agrochemicals and consequently increasing profits and decreasing ground water contamination. Citrus fruits are Florida's largest agricultural commodity, producing over 80% of the United States' supply of citrus and are second only to Brazil in orange production (Hodges *et al*. 2001). Florida citrus groves are managed as large, continuous, uniform blocks although there are variations in tree sizes and yield. Variable rate fertilization on a tree size basis could considerably enhance the profitability of groves and environmental protection (Zaman *et al*. 2005).

BACKGROUND

The USA used 10.9×10^6 MT of nitrogenous fertilizers in 2005, which is an 8% increase over the last 15 years where as the production declined from 13.1×10^6 MT in 1990 to 7.7×10^6 MT in 2005 (FAO 2008). The trend of production and consumption of nitrogenous fertilizer in the United States is illustrated in **Fig. 1**. Although the demand and consumption maintained steady, N-fertilizer production declined, especially after the mid-nineties and resulted in consumption surpluses in 1999.

Urea is the most commonly used nitrogenous fertilizer in Florida's citrus groves. However, uniform conventional fertilizer application practice disregards the productive potentials of the various areas within the field. Thus, some areas end up with more soil nutrition than others. An increase in the levels of fertilizer generally increases the crop yield up to an optimum level, but less of the excess fertilizer will utilized or mobilized. Another important issue is that nitrogen from fertilizers may be lost into the atmosphere or enter streams through surface or subsurface drainage (leaching). Thus, over-fertilization is a potential source of pollution in the form of ammonia (NH_3), nitrite (NO_2), and nitrate (NO_3), which may pose a hazard to human health. Therefore, a contemporary issue is how to give an effective dose at the accurate position and right time for optimum growth of crops, while preserving the environment without causing economic losses (Iida *et al*. 2001).

Precision farming or site specific management assists growers in the decision making process involving the use of inputs. Variable rate nitrogen fertilization is one of the useful ways of reducing production costs and conserving nitrate. Comparison of costs and economic profitability of conventional methods and that of using precision technology in any crop production is necessary for a grower about to adopt any new technology. One such study was conduc-

Received: 1 August, 2008. Accepted: 19 December, 2008.

Invited Mini-Review

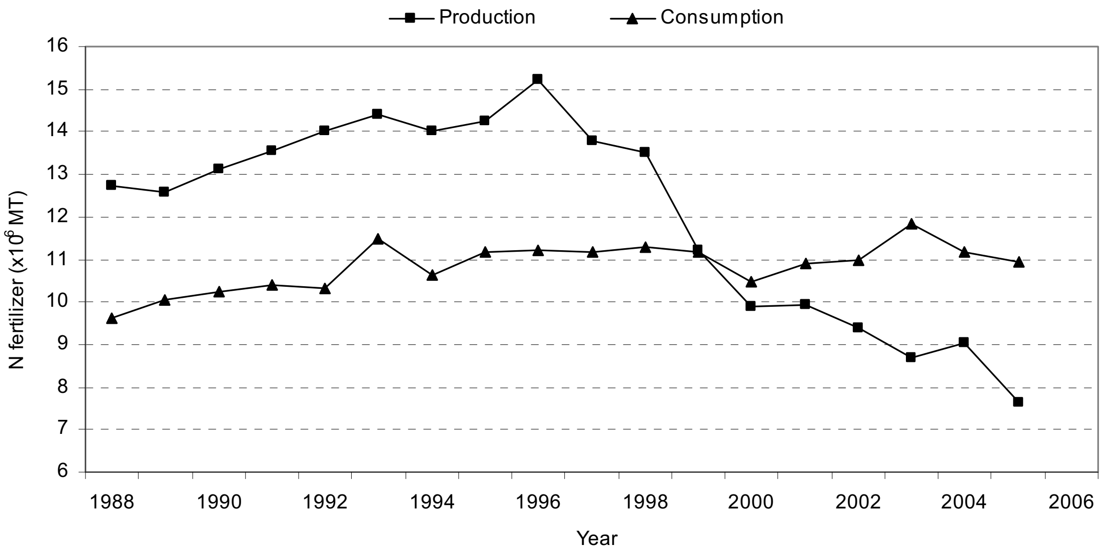

Fig. 1 Trend of production and consumption of nitrogenous fertilizer in the USA. (Source: redrawn from FAO, 2008)

ted by Silva *et al*. (2007) using simulation to analyze viability indicators with the help of net present value and the internal rate of return methods.

Sevier and Lee (2004) conducted a probit analysis with decision to adopt as the dependant variable which indicated that variables associated with age of a grower and grove variability, had significant influences on the decision to adopt a new technology. Elder growers were reluctant to adopt precision agricultural technology tools, including variable rate technology (VRT); even though moderate and maximum in-grove variability when compared to minimum in-grove variability, were positive influences on the decision to adopt such technology. Sevier and Lee (2005) analyzed adoption process and investment decision made by an existing citrus caretaking organization. They concluded that the organization saved approximately $34/ha in a plot of 70 ha and $55/ha on a plot of 4 ha in one year after the adoption of a VRT fertilizer spreader system using urea.

Batte and Arnholt (2003), analyzed case studies of six leading-edge farms in Ohio, which adapted precision farming technologies and concluded that the benefits depended on the unique problems faced by the farm (e.g. soil pH, fertility, drainage) and perhaps on the analytical style and managerial strengths of the individual farmer.

Environmental non-point pollution (NPP) problems associated with agricultural practices have come under increasing scrutiny in recent years. Agricultural practices are considered the largest contributor of surface water quality degradation in terms of sediment, runoff of nutrients, and leaching of chemicals (Crutchfield *et al*. 1993). Variable rate application of chemicals can limit the amount of nutrient and chemical runoff to the environment because they precisely match fertilizer and pesticide application to the needs of the crop. Intrapapong *et al*. (2003) used a bio-economic model to investigate the environmental and economic impacts of variable-rate fertilizer application, as compared with a conventional, single-rate application and the empirical results demonstrated that VRT could provide both environmental and economic benefits when used on cotton, soybeans, and corn in Mississippi. With 50% of the urban population and more than 90 percent of the rural population relying on groundwater as their primary source of drinking water (USEPA 1987), nitrate leaching is a public health concern. Although the long-run public health effects of consuming nitrate-contaminated water are not clearly understood, government regulators have made efforts to reduce nitrate leaching (Vickner *et al*. 1998).

This study was undertaken to review the economic and environmental impacts of variable rate fertilization in Florida's citrus groves. Specific considerations were given to estimate the monetary savings and reduction of urea applied in adapting VRT under different scenarios, without decreases in citrus yield.

Present VRT Technologies

Though precision farming technologies have been adapted in Florida's citrus groves, it is still in the experimentation stage. A granular fertilizer spreader (M&D, Arcadia, Fla.) equipped with a control package (Chemical Containers, Lake Wales, Fla.) is available in Florida for variable rate fertilizer application (Miller *et al*. 2003). A MidTech Legacy 6000 controller and radar speed sensor (Midwest Technologies; Springfield, Ill.), 10-Hz Trimble AgGPS132 (Trimble; Sunnyvale, Calif.), six Banner QMT42 long-range diffuse photocells (Banner Engineering, Minneapolis, Minn.) to detect tree canopy on each side of the spreader and a switch box (Chemical Containers, Lake Wales, Fla.) comprises the main control elements external to the fertilizer unit. The unit is equipped with modulating hydraulic control valves, positioned by a 12-V signal, to regulate chain speed for left and right side discharge. A Dickey-John Land Manager® II control system, which consists of a control valve on each side of the spreader has been tested by Citrus Research and Education Center, University of Florida, Lake Alfred, Florida; to replace the MidTech Legacy 6000 controller as the latter has poor response time for application rate change. Initial tests showed encouraging results as Dickey-John Land Manager® II control system has better response time for rate change (Schumann *et al*. 2005).

Variable rate N application

Variable rate fertilizer applications can be based on either the previous years yield (yield map) or height and/or canopy volume of an individual tree. Zaman *et al*. (2005) have done an experiment on variable rate fertilization and they found substantial variation in tree canopy volume (0 to 240 m^3) and the excess levels of N in the medium to small trees within the grove. They emphasized the need for variable rate application of N on a single tree basis and reported that VRT fertilization saved 38 to 40% that corresponds to savings of US$138/ha (considering 40% urea savings) as compared to the grower's uniform rate of 270 kg N/ha/y. This has enhanced the performance of the Ridge Citrus N-BMPs in Florida, both economically and environmentally by avoiding over-fertilization on each tree rather than on an entire averaged grove (Schumann 2003). An experiment was conducted in a 17-ha citrus grove of 'Valencia' variety in Florida. Half of the grove was treated with VRT according to canopy volume of individual trees and the other half were treated with uniform rate technology (URT). The

Table 1 Amount of urea used in variable rate application, uniform rate application and savings of urea due to VRT

Area (ha)	Classes, tree vol. (m^3)	Variable rate application		Uniform rate application		Total difference N (kg)
		N rate (kg/ha/y)	Total N required (kg)	N rate (kg/ha/y)	Total N required (kg)	
0.83	0-4 (by hand)	25.6	21.2	269.5	223.6	202.4
1.74	4.1-47	134.7	234.4	269.5	468.8	234.4
3.02	47.1-90	168.4	508.6	269.5	813.7	305.1
1.22	90.1-132	202.1	246.7	269.5	328.7	82.2
1.40	132.1-175	235.8	330.2	269.5	377.2	47.1
0.28	>175	269.5	75.5	269.5	75.5	0.00
Total			1416.4		2287.6	871.2

Source: **Zaman QU, Schumann AW, Miller WM** (2005) Variable rate nitrogen application in Florida citrus based on ultrasonically-sensed tree size. *Applied Engineering in Agriculture* **21**, 331-335, with kind permission from the American Society of Agricultural and Biological Engineers, ©2005.

results are shown in **Table 1**. The amount of fertilizer applied to 8.4 ha of citrus grove was 1416.4, where as 2287.6 kg of fertilizers were applied to the other 8.4 ha of grove treated with URT. This variable rate application resulted savings of more than 104 kg/ha.

Economic benefits

The savings in fertilizer can be converted into economic benefit as it reduces the production cost resulting in higher profit from the grove. The area under citrus grove in Florida has decreased from 2.53×10^5 ha in 1996-1997 to 1.93×10^5 ha in 2006-2007. It may be due to real estate boom in the state in that period, infestation of trees by citrus canker or hurricanes. The citrus fruits production has increased gradually and declined substantially in last couple of years as can be seen from **Fig. 2**. To increase the yield substantially requires better management practices and optimum use of inputs like water, fertilizer and chemicals. This will also have environmental benefits, including decreases in non-point pollution through N leaching.

Hodges *et al*. (2001) explained that the environment of Florida provides a comparative advantage for citrus production due to the subtropical climate and abundant water resources and illustrated the economic structure of the Citrus industry. **Fig. 3** shows how inputs like agrochemicals and fertilizers can impact the economy as well as the environment of an area. Koch *et al*. (2004) studied variable rate N applications utilizing site specific management (SSM) zones based on a variable yield goal and found to be more profitable than uniform application. This resulted in a reduction in N fertilizer application and an increase in N use efficiency due to identification of management zones. They also found that site specific management zones along with variable yield goal strategy produced additional net returns.

Yields likely will increase on some field sites and decrease on others, relative to a uniform input application strategy. Likewise, the level of usage of fertilizers, pesticides and other inputs will vary unpredictably relative to URT. Farm total fixed costs are predicted to rise with SSM due to durable investments in machinery, mapping and resource inventories, and human capital. Profits associated with the SSM investment will be determined by the relative changes in revenues and costs (Batte 2000). The costs and profits of SSM will also be impacted by the size of the adopting farm. Economies of scale will be important for this technology, as it would be with any capital-embodied technology. Larger farmers will have a greater profit potential, and thus will predominate the early adopters of this technology. This may also mean that SSM, ultimately, will accelerate the trend toward larger, but fewer farms.

Though the initial investment is higher for adapting to VRT fertilizer spreader, the savings in fertilizer would payback the initial cost. A VRT spreader costs approximately $29,000 (Sevier and Lee 2005). An experiment by Zaman *et al*. (2005) showed savings of 40% savings in fertilizer amounting US$ 138/ha. Even considering a moderate reduction of 15% in urea, it would save $52/ha and 558 ha of use would pay for the spreader.

Florida accounted for 1.93×10^5 ha of land under citrus production in 2006-2007. If a portion of the area adapts VRT application of N fertilizer, the savings in terms of fertilizer and corresponding economic benefits would be enormous. **Table 2** shows the matrix of a different percentage of savings at a different percentage of area under VRT adoption. There is a potential of savings of up to 10.7 million US

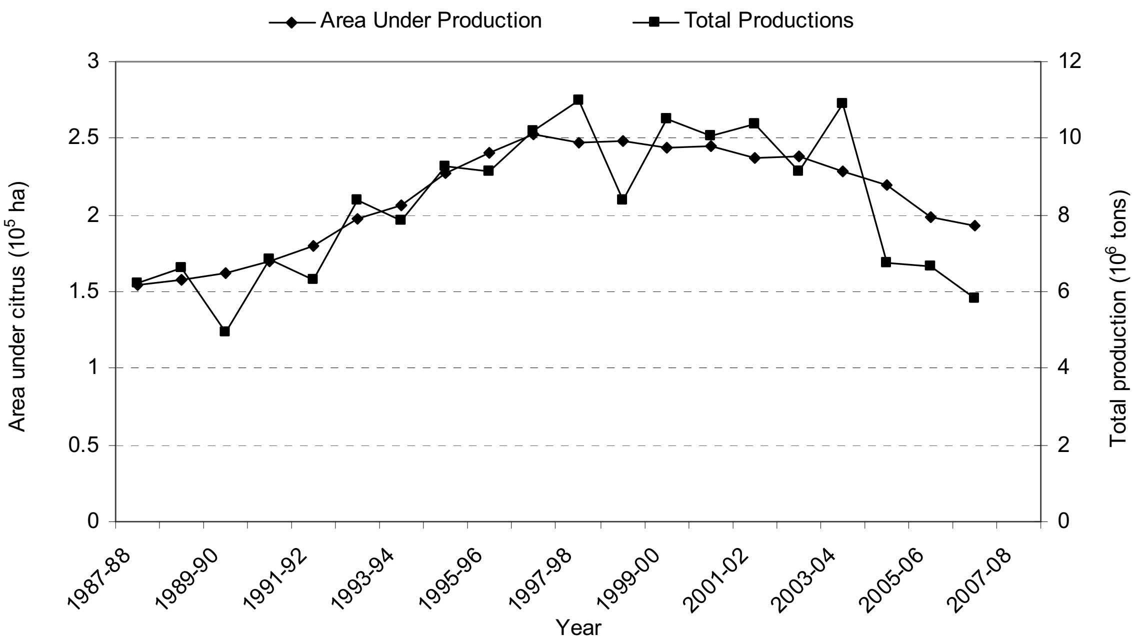

Fig. 2 Trend of annual production and area covered by Florida's citrus industry. (Source: redrawn from Florida Agricultural Statistics Service 2008).

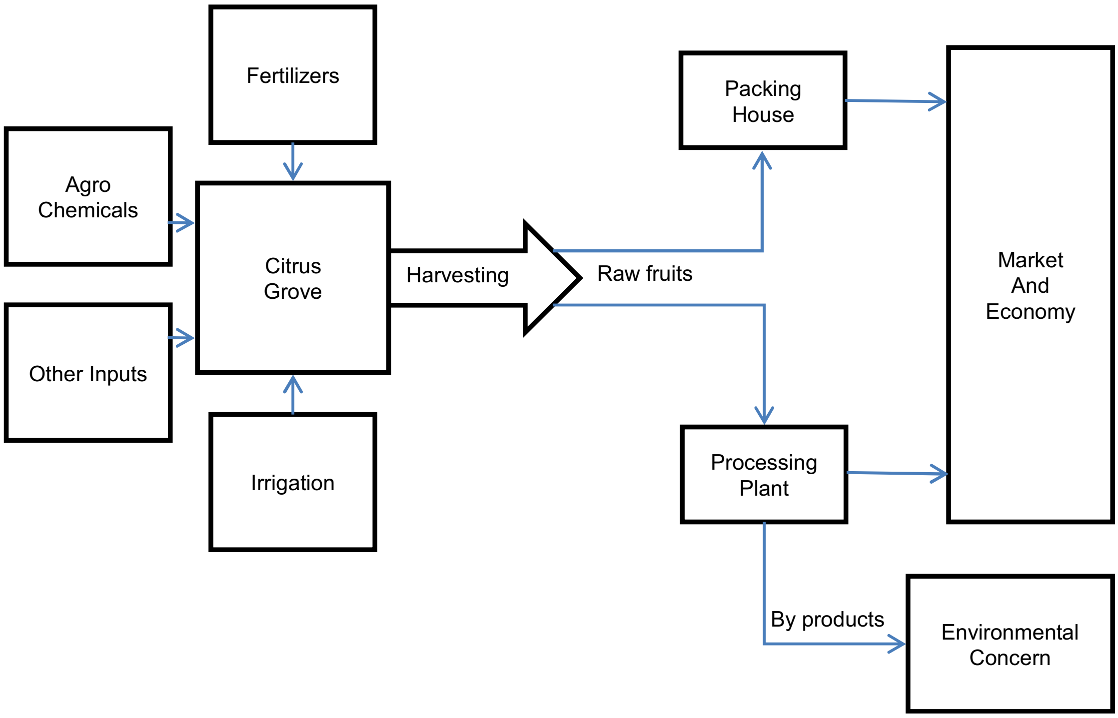

Fig. 3 The structure of the Florida's citrus industry.

Table 2 Savings in dollars at various percentage of area under VRT fertilization.

Percent Fertilizer Savings	Savings in US$	
	15% area under VRT	40% area under VRT
15	1,505,400	4,014,400
40	3,995,100	10,653,600

dollars, considering 40% savings of fertilizer and 40% of the citrus groves utilizing VRT fertilization. Even a moderate savings of 15% of urea and 15% of the groves in the state adapts VRT; the amount will be to the tune of 1.5 million US dollars.

Environmental benefits

Environmental impacts would follow the economic benefits as the amount of fertilizer applied would decrease. It would be difficult to quantify the reduction in environmental damages due to VRT, but the reduction in fertilizer and agrochemicals can be estimated. Environmental costs and benefits are external to the farm. Farmers, when making the precision farming decision, will not consider these values sometimes. If it is determined that VRT has significant environmental value to society, adoption could be speeded by either transferring external costs back to non-adopter farmers through a tax mechanism, or rewarding adopters with a subsidy (Batte 2000).

The experiment conducted by Zaman *et al.* (2005) used a uniform rate of 270 kg/ha/year, which is common in Florida. Citrus groves in Florida would need 5.2×10^7 kg/year of N fertilizer for 1.93×10^5 ha under fruit production. Any reduction in the amount of fertilizer application would result in decreasing N leaching and also a decrease in ground water contamination. **Table 3** shows the matrix of amount reduced if certain percentage of groves adapts to VRT fertilization. There is a potential of 8.34 million kg/year reduction of urea, considering 40% savings in fertilizer application and 40% of the area under VRT. With a moderate savings of 15% when 15% of groves adapts VRT; 1.17 million kg of urea can be reduced without having affecting the citrus yield.

Table 3 Amount of fertilizer savings at various percentage of area under VRT fertilization.

Percent Fertilizer Savings	Amount of fertilizer savings in kg/year	
	15% area under VRT	40% area under VRT
15	1,172,000	3,127,500
40	3,127,500	8,344,000

CONCLUSIONS

The savings from reduced fertilizer expenditure would not only result in economic benefit to the citrus grove, but also have environmental benefits by adding less chemicals to the soil. This would also help in bridging the gap between fertilizer production and consumption in recent years and result in less nitrate leaching, as the amount of N fertilizer would be less through VRT. Variable rate fertilizer application would also improve the fruit quality and fertilizer uptake efficiency. VRT has the potential of 40% reduction in nitrogen fertilizer use, such as urea. This would account for savings of 8.3 million kg of urea amounting to US$ 10.7 million, considering 40% of the groves in Florida adapts to VRT. Even at a moderate assumption of 15% of the citrus groves adopting VRT, this translates to a minimum savings of 15% and a reduction in the use of 1.2 million kg of urea, which corresponds to $1.5 million. More and more growers are realizing this benefit.

REFERENCES

Batte MT, Arnholt MW (2003) Precision farming adoption and use in Ohio: case studies of six leading-edge adopters. *Computers and Electronics in Agriculture* **38**, 125-139

Batte MT (2000) Factors influencing the profitability of precision farming systems. *Journal of Soil Water Conservation* **55 (1)**, pp 12-18

Crutchfield SR, Hansen LT, Ribaudo MO (1993) Agricultural and Water Quality Conflicts: Economic Dimensions of the Problem. AIB-676, United States Department of Agriculture, Economic Research Service, Washington DC, USA 20 pp

FAO (2008) FAOSTAT data. Available online: http://www.fao.org

Florida Agricultural Statistics Service (2008) *Citrus Summary 2006–07*, Tallahassee, Florida, USA, 48 pp February 2008

Hodges AE, Philippakos DM, Spreen T, Muraro T (2001) Economic impact of Florida's citrus industry, 1999-2000. Economic Information Report 01-2, University of Florida, Gainesville, Florida, USA, 14 pp

Iida M, Umeda M, Radite PAS (2001) Variable rate fertilizer applicator for paddy field. ASAE Paper No. 011115. St. Joseph, Mich.: ASAE

Intrapapong W, Hite D, Hudson D (2003) Economic and environmental impacts of variable-rate fertilizer application in Mississippi. Mississippi Agricultural & Forestry Experiment Station: Bulletin 1129, Mississippi State University, Mississippi State, MS, USA, 17 pp

Koch B, Khosla R, Frasier WM, Westfall DG, Inman D (2004) Economic feasibility of variable-rate nitrogen application utilizing site-specific management zones. *Agronomy Journal* **96 (6)**, 1571-1580

Miller WM, Schumann AW, Whitney JD, Buchanon S (2003) VRT citrus test plot applications of granular fertilizer. ASAE Paper No. 031127, ASAE, St. Joseph, MI, 14 pp

Schumann AW (2003) Nutrient BMPs for the ridge citrus production region. In: Futch SH (Ed) *Proceedings of Nutrient Management for Optimum Citrus Tree Growth and Yield Short Course*, 29 October 2003, Lake Alfred, FLA, USA, pp 98-112

Schumann AW, Miller WM, Hostler HK, Buchanon S, Bora GC, Cugati S (2005) Citrus fertilization studies on sandy soils and the use of variable rate technologies. Presented at Florida Growers Institute, South Florida Community College, Lakeland, Florida, USA, 20 pp

Sevier BJ, Lee WS (2004) Precision agriculture in citrus: a probit model analysis for technology adoption. ASAE Paper No. 041092, ASAE, St. Joseph, MI, 13 pp

Sevier BJ, Lee WS (2005) Precision farming adoption in Florida citrus: A grower case study. ASAE Paper No. 051054, ASAE, St. Joseph, MI, 12 pp

Silva BC, Ribeiro do Vale SML, Pinto FAC, Műller CAS, Moura AD (2007) The economic feasibility of precision agriculture in Mato Grosso do Sul State, Brazil: A case study. *Precision Agriculture* **8 (7)**, 255-265

USEPA (1987) Improved protection of water resources from long-term and cumulative pollution: prevention of ground-water contamination in the United States. Office of Ground-Water Protection, United States Environmental Protection Agency, Washington DC, USA, 138 pp

Vickner SS, Hoag DL, Frasier WM, Ascough JC (1998) A dynamic economic analysis of nitrate leaching in corn production under nonuniform irrigation conditions. *American Journal of Agricultural Economics* **80**, 397-408

Zaman QU, Schumann AW, Miller WM (2005) Variable rate nitrogen application in Florida citrus based on ultrasonically-sensed tree size. *Applied Engineering in Agriculture* **21**, 331-335