Developments in Precision Agriculture Use in Asia

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Session 6b: Tools, Techniques, Innovations

Introduction

Skepticism of the applicability of precision agriculture in developing Asia has long since been supported by myriad of concerns around plot size, timing and weather, expertise and ground-level capacity, and, importantly, access to sufficient capital to support investment. New developments in South Asia are revealing that despite high parcel density and low income levels, precision technologies can make a significant difference in livelihoods of equipment operators and farmers. Moreover, a new investment model is emerging that is facilitating greater adoption of precision technologies, and subsequently is allowing the benefits of technology use to reach more people faster. This brief will examine the costs and benefits of laser land leveling in the geographic region of Southeast Pakistan and Northwest India, and discuss the investment model which is supporting the adoption of technology at the farm level. In addition to laser land leveling, which is a technology proven to increase water use efficiency, we will also explore the use of optical sensors to monitor the normalized difference vegetation index (NDVI) for individual crops, which may be used to reduce over-irrigation and improve nitrogen-use efficiency.

A New Model for Laser Land Levelling in Southeast Pakistan and Northwest India

The figures below are indicative of the costs and benefits the average equipment operator and the average farmer who are cultivating near the India-Pakistan border are realising following the adoption of laser land levelling. This region, comprised of the states of Sindh and Punjab in Pakistan and Punjab, Rajasthan, Haryana and Gujarat in India, has the highest acceptance rate of precision farming technologies in Southern Asia. Geographically, it represents about than 60% of the arable land in Pakistan and 20% in India. Cereal crops are grown commercially and contribute a major portion of procured grain in both countries. In dollar terms, the costs and benefits of laser land levelling are relatively even between the two countries aside from roughly 20% higher agricultural input costs and 20% lower labour costs in Pakistan. Table 1 is summary of income data derived from field inquiries, Trimble customers in the region, and recent academic studies.

The results of Table 1 should be no surprise to those familiar with the literature surrounding laser land leveling. It is universally recognized that laser land leveling not only improves the economic situation of equipment operators and farmers, but also provides a number of positive externalities. Most important to areas adversely affected by poor water management, laser leveling supports sustained efficient

water use, which can alleviate pressures put on irrigation infrastructure as well as local aquifers. In most studies, the volume of water needed for irrigation after laser leveling decreased by between 25% and 50%. In arid regions, marginal decreases in water use can be the most impactful, freeing up water for vegetable and fruit crops or human consumption.

Despite its proven results, until recently laser land leveling was not widely used as a means to improve agricultural productivity. In much of rural Asia, sufficient capital for purchase of a tractor and leveling equipment was either inaccessible or expensive. Currently, formal lenders in the region of focus charge close to 20% interest for microloans, while informal rates jump to as high as 35%. However, subsidy programs initiated by the governments of India and Pakistan, often with the help of multilateral development institutions, are facilitating the adoption of laser leveling technology on a greater scale. One of the key advances has been the provision of technology-specific subsidies to borrowers both for the initial purchase of equipment as well as interest payments. In addition, borrowers are given a choice of high-performance equipment that has been subject to field testing. The subsidy acts as a cushion for borrowers, who would otherwise be extremely price conscious, to invest in quality performance. Equipment providers are also engaged, offering training and services to develop their market. This effort combines to produce the performance numbers as seen above, allowing the borrower to easily pay back their microloan within two to three years. As many borrowers are only one of a handful of equipment owners in their community, they are able to maximize the use of their equipment during the appropriate seasons, increasing the geographic footprint gradually.

Optical Sensors Applied to Reduce Nitrogen Inputs in Northwest India

As seen in Table 1, despite the significant gains in yield, reduction in water and power, and increase in profit per acre cultivated, the amount of agricultural inputs, including seed, pesticides, and fertilizers, are not decreasing. Over the past decade a combination of commodity price fluctuation, water scarcity, and seed availability have produced a significant shift away from rice cultivation to wheat cultivation in India. This change is most evident in the northwest, India's breadbasket, where farmers cultivate large volumes of wheat for national consumption. For years, nitrogen added to wheat crops was applied in a blanket fashion, spraying entire wheat tracks with excessive quantities in hopes of ensuring crop yield. This method of application achieves very low nitrogen-use efficiency and fails to account for variations of soil quality between regions and even plots of land. New studies conducted by a consortium of India's leading agricultural scientists, has applied Trimble's GreenSeeker™ optical sensing system to the nitrogen use problem. GreenSeeker™ is a solution which examines the NDVI value for individual plants and applies nitrogen according to individual plant needs in a precise manner. This method effectively localizes nitrogen application at the plant level, tailoring nitrogen application based on the need for nitrogen at a given period in the

growth cycle. The consortium has defined a fertilizer nitrogen algorithm based on expected yields and achievable greenness of the plant. Because nitrogen is applied numerous times over the course of the growth cycle, GreenSeeker™ was found to be an excellent solution for increasing efficiency of nitrogen application once the crop was above ground, usually following an irrigation event. More importantly, because GreenSeeker™ introduces the capability to tailor nitrogen application at the plant level, the solution was used largely in tandem with a lower initial blanket application of fertilizer nitrogen at the early stages of growth prior to irrigation.

The GreenSeeker™ offers the individual farmer an overall reduction in required nitrogen inputs in wheat cultivation. Meanwhile, while GreenSeeker™ was traditionally developed for large mechanized machinery, Trimble has developed a handheld application which is more suitable for the Asian farmer. In areas where water is increasingly scarce and supplemental fertilizer inputs are therefore critical to guarantee yields, this solution is becoming more and more attractive.

Opportunities and Recommendations

Precision agriculture tools can be used effectively in the Asian context, and to many followers of these technologies, this is not a new realization. What has remained a challenge, however, is the selection of a financial model that facilitates the adoption of technology in Asian agriculture. In South Asia alone, the introduction of these technologies to Southern India, Northwest Bangladesh, and Southern Nepal remains an objective of industry and development organizations alike. Southeast Asia, similarly, holds tremendous potential for technology use, however the approach may vary drastically between markets. From industry's perspective, the discussion in the developing markets cannot focus heavily on cost savings and profits, however, but more on food security, sustainability, and on how technology can support the beginning stages of the agricultural goods supply chain.

Subsidy programs, such as the ones described in this paper, offer one possible solution for the adoption of precision agricultural technology. What is different about the recent subsidy programs in India and Pakistan is the introduction of market mechanisms for selection and application of the technology by the individual farmer. This method engages the farmer and encourages him or her to monitor the impacts precision technology has on their yield and operating costs. Trimble's involvement in many of these projects has also been positive, primarily because quality and performance of the technology have been at the forefront of the discussion between subsidy providers, equipment owners, and farmers.

The introduction of lease-financing for equipment may further alleviate the financial burden and reduce investment risk, all the while allowing disadvantaged rural populations access to yield-increasing technologies. Lease-financing holds further attractiveness in very poor parts of the agricultural base because even in a subsidy program there is difficulty in amassing sufficient capital to purchase

technology. Lessors may also achieve scale, which would facilitate a low marginal cost for training and maintenance. This is another financing model that deserves additional debate and consideration when developing assistance programs and policies.

Table 1: Average Equipment Operator and Farmer Performance

Levelling Equipment Owner Performance (US$)

	hour(s)	Income
Hourly Wage	1	$10
Time required per Acre	3	$30
Total Daily Wage	10	$100
Total Seasonal Wage*	1200	$12,000
Annual Operating Costs		$6,000

**Levelling season is 4 months; 3 in summer & 1 in winter*

Farmer Performance (Rice & Wheat combined, US$)

	w/o Laser Levelling	w/ Laser Levelling	Percentage Change
Yield	$840	$1,000	19%
Water & Power Use	$84	$70	-17%
Labor	$146	$180	23%
AG inputs*	$150	$150	0%
Annual Income per Acre	$840	$1,000	19%
Annual Profit per Acre	$500	$600	20%

**includes pesticides, seeds, fertilizers, etc.*

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Land Leveling – Techniques and Benefits

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Session 6b: Tools, Techniques, Innovations

Introduction

Leveling rice fields improves water efficiency, increases grain yield and improves grain quality.

Leveling Land improves water coverage which:

- Reduces the amount of water required for land preparation
- Improves crop establishment
- Decreases the time to complete tasks
- Results in better crop stands
- Reduces weed problems
- Results in uniform crop maturity
- Overall increasing yields and profitability for the farmer

Methods of Land Leveling

Different Systems require different field conditions and operating time to complete the task:

Draft animals and 2-wheel tractors using harrows and leveling boards

These leveling techniques require total water coverage of the field and require 7 to 8 days for 2-wheeled tractor and 12 days per hectare of land using draft animals.

Four wheel tractor using rear mounted tractor blades or drag buckets.

- Wet Fields use a rear-mounted tractor blade.
- Dry fields use hydraulically operated drag buckets.
- Work rates are dependent on the tractor size and the amount of soil to be moved. It will take approximately 8 hours to level 1 hectare with a rear mounted tractor blade.

Four wheel tractor with a laser control bucket

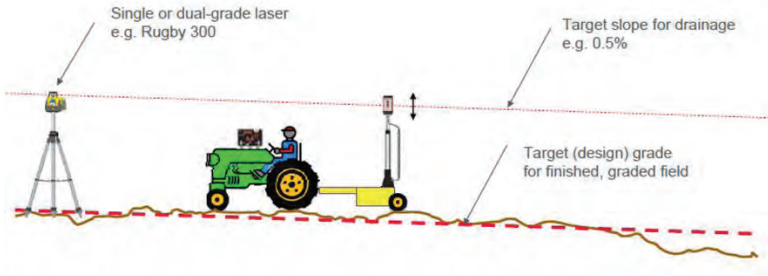
- The use of laser controlled equipment results in a much higher accuracy for the field leveling. Accuracy can be improved by as much as 50%.
- Time taken to level one hectare reduces to about 4 hrs when using a drag bucket, this can be further reduced when working with laser control, the main benefit in addition being accuracy and ease of use.

What is Laser Land Leveling?

Laser leveling is a user guided precision leveling technique used for achieving very fine leveling with desired grade on the agricultural field. Laser leveling uses a laser transmitter unit that constantly emits 360^0 rotating beam parallel to the required field plane. This beam is received by a laser receiver (receiving unit) fitted on a mast on the scraper unit. The signal received is converted into cut and fill level adjustments and the corresponding changes in scrapper level are carried out automatically by a two way hydraulic control valve.

Laser leveling maintains the grade by automatically performing the cutting and leveling operations. Both level grade and slope grade (one way or two way) can be achieved with the help of this precision equipment. The field is cultivated and planked before using the Laser Land Leveler. A grid survey is performed using grade rod to identify highs and lows in the field and mean grade is found. A grid spacing of 10m x 10m is maintained for accurate land survey; however this spacing can be varied depending upon the size of the field.

For practical purposes and with experience, grid survey can be done by pacing off the distances rather than (measuring). A map is then drawn to indicate which areas are high; require soil to be cut and the lows which require soil to be added. The Tractor pulls Earth from the high area to the low area. Generally fertile top soil is removed before leveling, and replaced thereafter. Different regions will have a different depth of top soil, so it is important to understand the soil mechanics before we start leveling.



Why precise Land Leveling using Laser Based Land Leveling Systems?

Unevenness of the soil surface has a major impact on the germination, stand and yield of crops through nutrient water interaction and salt and soil moisture distribution pat-tern. Land leveling is a precursor to good agronomic, soil and crop management practices. Resource con-serving technologies perform better on well leveled and laid-out fields.

Farmers recognize this and there-fore devote considerable attention and resources in leveling their fields properly. However, traditional methods of leveling land are not only more cumbersome and time consuming but more expensive as well. Very often most rice farmers level their fields under ponded water conditions. The others dry level their fields and check level by ponding water. Thus in the process of having good leveling in fields, a consider-able amount of water is wasted.

It is a common knowledge that most of the farmers apply irrigation water until all the parcels are fully wetted and covered with a thin sheet of water. Studies have indicated that a significant (20-25%) amount of irrigation water is lost during its application at the farm due to poor farm designing and unevenness of the fields. This problem is more pronounced in the case of rice fields. Unevenness of fields leads to inefficient use of irrigation water and also delays tillage and crop establishment options. Fields that are not leveled have uneven crop stands, increased weed burdens and un-even maturing of crops.

All these factors tend to contribute to reduced yield and grain quality which reduce the potential farm gate income. Effective land leveling is meant to optimize water use efficiency, improve crop establishment, reduce the irrigation time and effort required to manage crop.

An Overview from Research

IRRI's Joseph F. Rickmann found the following during research carried out in SE Asia:

Crop Yield

- Results of land leveling experiments conducted in rainfed fields in Cambodia found the average increase in crop yield was 24% or 530 kilograms per hectare.
- A strong correlation was found between the levelness of the land and crop yield. For every 10mm in surface variation there was a yield loss of 260Kg of grain.

Weed Control

- Improved Water Coverage from Land Leveling reduces weeds by up to 40%
- Less time was needed for crop weeding. A reduction from 21 to 5 labour days / ha was achieved.

Farm Operations

Land levelling facilitated the use of larger fields. This can be critical and has occurred during mechanisation in advanced Countries over many years.

- Increasing farm size from 0.1 hectare to 0.5 hectare increases the farming area by 5–7%.
- Reshaping fields can reduce operating times by 10% to 15%.

Efficiency of Water use

The average difference in fields—highest to lowest portions of rice fields in Asia was 160mm. This means:

- An extra 80mm to 100mm of water had to be stored in the field to give complete coverage.
- Water in the higher fields was able to be used in the lower fields for land preparation, plant establishment and irrigation.

Other benefits and Opportunities

- Plough the field on time
- Harvest evenly ripened crop
- Shed Flood waters more rapidly

Cost of Land Leveling

- The costs vary according to the topography, the shape of the field and the equipment used.
- Cost ranges from $3 to $5 per 10mm of soil moved per hectare.
- Laser Land Levelling is 24 times more efficient in terms of time than using Animal and Leveling boards.

	Animal + leveling board	2-wheel tractor + harrows	4-wheel tractor + blade
Purchase price ($)	500	1000	12,000
Time (days)	12	7	0.5
	Operating cost $/ha		
Labor	15	9	2.5
Fuel & oil		22	32.5
Repairs		5	7.5
Pumping costs	6	6	
	Fixed Cost $/ha		
Depreciation or Replacement cost	12	4	7.5
Total Cost ($ ha-1)	33	46	50

- Less Labour costs.
- The application of additional fertilizer, especially phosphate is necessary in areas from which soil is moved, especially when top soil is not reinstated.
- Re-leveling the whole field should not be necessary for at least eight to ten years. Little variation in surface topography after two crops.

Year	1	2	3	4	5	6	7	8
	Additional Cost ($ ha-1)							
Leveling	50	0	0	0	0	0	0	0
Ploughing	15	0	0	0	0	0	0	0
Fertilizer	13	6	0	0	0	0	0	0
	Benefit ($ ha-1)							
Grain yield	53	53	53	53	53	53	53	53
Reduction in weeding	8	8	8	8	8	8	8	8
Cumulative cash flow	-17	38	99	160	221	282	343	404

Financial Benefits of Land Leveling

- A cash Flow analysis over a period of years shows that the financial benefits do result from Land Leveling.
- This is based on 530 Kilograms of additional yield per hectare, therefore $53 per hectare additional revenue.
- The costs allow for an extra ploughing and extra fertilizer in the first and second years. The benefits include reduced weeding cost of up to 40%.

India – Case Study

Declining water table and degrading soil health are the major concerns for the current growth rate and sustainability of Indian Agriculture. Thus proper emphasis

is being given on the management of irrigation water usage for adequate growth of agriculture. Keeping in view, the need for judicious use of our natural resources, concerted efforts are being made to enlighten the farmers for efficient use of irrigation water at farm level. Generally, in rice wheat rotation farmers believed that their fields are leveled and needed no further leveling. But the digital elevation survey sheet of a field shows that the most of the fields are not adequately leveled and require further precision land leveling.

The enhancement of water use efficiency and farm productivity at field level is one of the best options to redress the problem of declining water level in the Punjab India. The planner and policy maker are properly in-formed and motivated to develop strategies and programs for efficient utilization of available water resources. Laser Land leveling is one such important technology for using water efficiently as it reduces irrigation time and enhances productivity not only of water but also of other non-water farm inputs. Results in technologically advanced countries have indicated that saves water to the tune of 25–30% and time by 30% and also improves the productivity by 10–15%. It has also been ob-served that with Laser Land Leveling 2–3% effective cropped area in case of flat fields and even more in ridge sown fields become available for cultivation of crops, as the number of bunds and irrigation channels get reduced considerably.

Benefits of Land Leveling in India

Effective land leveling reduces the work in crop establishment & crop management, and increases the yield and quality. Level land improves water coverage that Improves crop establishment, reduces weed problems, improves uniformity of crop maturity, decreases the time to complete tasks and reduces the amount of water required for land preparation.

Yield and irrigation water saving for Laser leveled and traditionally leveled plots for rice crop under replicated experiments at PAU, Ludhiana

Sr. No.	Leveled (t/ha)	Unleveled (t/ha)	% age increase in yield	% Saving in irrigation time/water
Site 1	8.78 ±0.33	7.73 ±0.21	13.60	26.15
Site 2	8.30 ±0.46	7.53 ±0.39	10.30	---
Site 3	7.60 ±0.21	7.00 ±0.25	8.57	25.00
Mean			10.82	25.57

Leica Rugby used for Laser Land Leveling Systems provide benefits to the farmers by precisely leveling the fields giving to the following benefits:

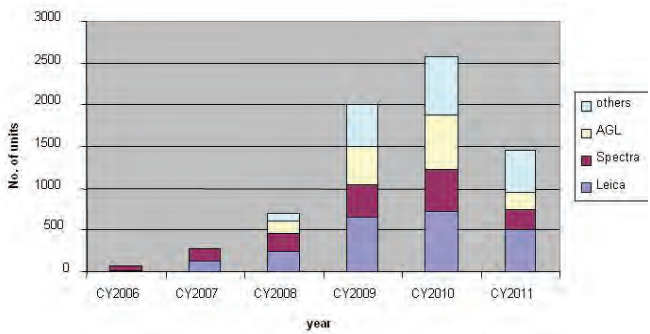
- Optimization of water use efficiency
- Better crop establishment
- Less Time and Water required in Irrigation
- Less effort in crop management
- Less weed problems
- Uniformity in crop maturity
- Time efficiency in completion of task
- Easy land preparation
- Less water requirement for land preparation
- Reduced consumption of seeds, fertilizers, chemicals and fuel
- Increase in farming area.
- Assist top soil management
- Saves fuel / electricity used in irrigation
- More uniform moisture environment for crops
- Good germination and growth of crop
- Improved field traffic, optimum area coverage.

Commercial Status – India

Commercially Laser Land Leveling has been a great success in India over the last 5–6 years. Majority of sales focused in a small State (Punjab) which is starting to reach saturation at around 7000 units in the field today.

Market size information – India

- Between 1500–2000 laser land leveler market in CY2011 (US$ 6-8 million)
- CY2011 market was almost lower by 40% compared to 2010, Weather conditions and market nearing market saturation contributing factors in the Punjab region.
- Hexagon Owned Brands, Leica Geosystems and AGL have more than 50% Market share in India at the present time.
- Increase in variety of brands in the market, showing the positive response to the technology.



Market growth information – India

- Market had been growing rapidly for last 3–4 years due to very good acceptability of new technology in India (Mainly in Punjab region)
- Punjab slowly becoming saturated with new market adoption slow.
- Next 2–3 years sales are expected to be flat. Growth acceleration would occur when other markets (other states) increase adoption of technology.

Summary

It is clear that Farmers have seen the benefit from Laser Land Leveling technology. The benefits as outlined previously have been reflected by increased yield outputs when utilised, also in various pilots proved to be the case throughout South East Asia. We are now seeing heavy adoption in China, as well as various parts of SE Asia such as Cambodia & Vietnam.

It is clear that Laser Land Leveling is an important tool in the mechanization process of Asian farming agronomics, ultimately assisting to increase yields of rice in the region, whilst assisting to improve water savings and irrigation management.

As a key tool in the process of mechanization and benefit for the whole agronomical chain, we must assist in the implementation process. Drivers for success have heavily been driven by government subsidies. Low income farmers require return on their investment within a short period (mainly additional yield and lower productivity costs). It is clear, assistance with "on the ground" business planning and funding have helped to grow this market segment, and as a consequence increase yield output, and water management.