LASER-CONTROLLED LAND LEVELING

for the Philippines

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CONTENTS

1 Introduction

Poor land consolidation, insufficient mechanization including lack of precision land leveling, and inefficient use of agronomic inputs are some of the major challenges in rice production. Significant sloping in rice lands (a slope >0.03% or more than a 3-cm rise over a 100-m distance) causes uneven water distribution that leads to many adverse effects such as hampered crop establishment, increased use of seed, water, fertilizer, and pesticides, to for the effects of an uneven field.

For a given field with a certain slope, if we increase the size of the field in one direction, the height at the elevated side will also be increased, which will require a lot more water to fully flood the field, e.g., for weed control. The slope is therefore limiting the possible maximum field size. These problems can be solved by applying LLL.

This module answers the following questions about LLL:

i) What is it?
ii) Why is it important for crop production?
iii) How do you properly conduct it?
iv) How do you estimate its cost and benefits?
v) Case study of LLL in the Philippines

2 Overview of Laser land leveling

2.1. What is laser land leveling?

A laser-controlled leveling system, as shown in **Fig. 1**, involves a soil-moving scraper bucket (sometimes called drag bucket) attached to a 4-wheel tractor. A laser transmitter unit with a rotating laser transmitter placed at the side of the field creates a horizontal laser plane of light above the field (**Fig. 2**).

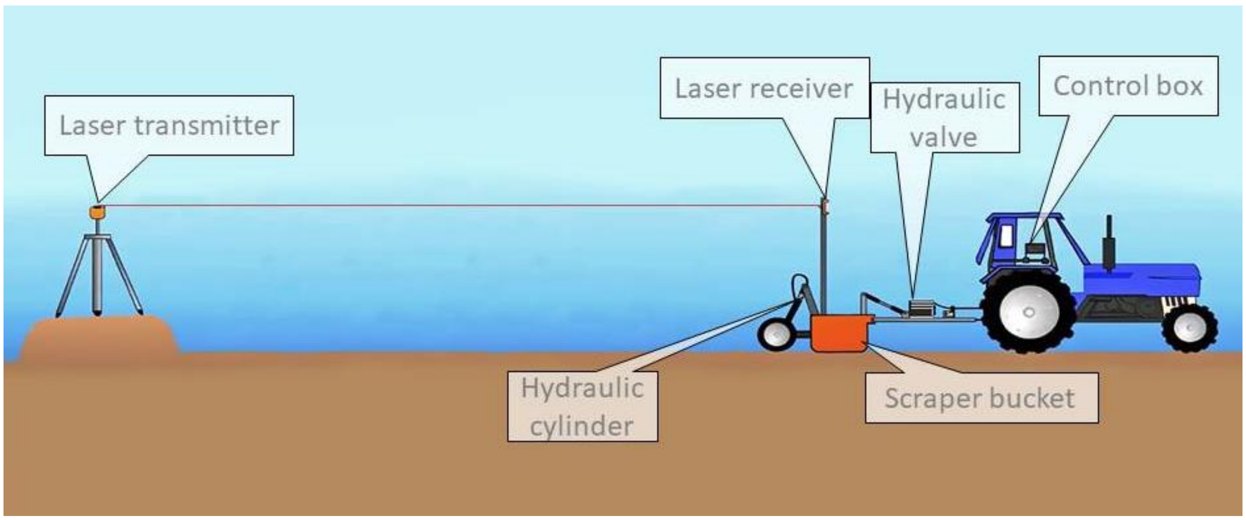


Fig. 1. Components of a laser-controlled land leveling system. Adapted from IRRI (2012); https://www.youtube.com/watch?v=kRAwyr6oK7Q)

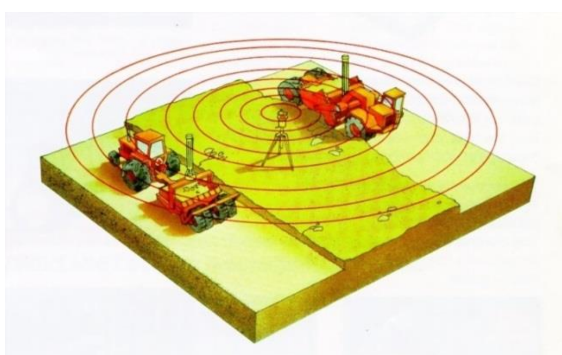


Fig. 2. LLL with stationary transmitter on a tripod creating a laser plane of light and two machines with receivers in the field. Source: Trimble (2018).

A laser receiver mounted on the scraper bucket measures the height of the scraper bucket relative to the laser plane of light and, through some electronic and hydraulic controls, adjusts the height of the scraper bucket according to the signals received. The mechanism keeps the scraper bucket always at the same height, resulting in the soil being scraped off and collected from the elevated areas of a field and getting dropped in the low areas. Compared to farmer practice or conventional soil-moving equipment, LLL enables extremely accurate leveling of fields under dry conditions.

2.2. Benefits of laser land leveling

Small-sized and uneven fields can cause poor management and low efficiency of agronomic inputs. It can also hamper mechanization and cause lodging of rice plant and non-uniform paddy at maturity stage leading to high postharvest losses (**Fig. 3a**).

Fig. 3a. Poor field leveling can cause difficulty in crop establishment (left) and crop lodging at maturity (right).

For example, assuming a small and a large field with the same slope, the larger dimension can lead to higher unevenness (**Fig. 3b**) resulting in more difficult management of water, fertilizer, pesticide, and in lodging.

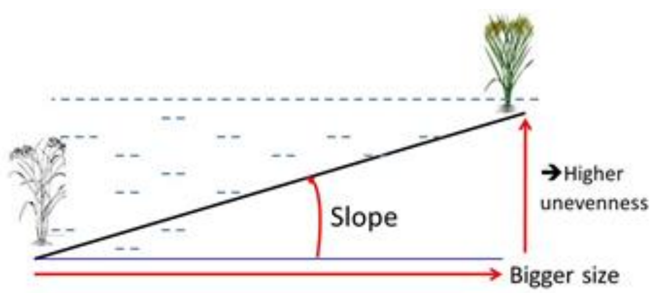


Fig. 3b. Slope and plot size diagram.

LLL technology can reduce the unevenness of the field surface to 1–2 cm height difference, even in a large field of 3 ha; in this case the field slope for draining the field can be set to 0.02%. Application of this technology can lead to an increase of land use efficiency by 20% when consolidating several small fields into one large field; savings of irrigation water by 20–60%; increases in fertilizer and pesticide-use efficiencies by 5–10%; and yield increases in rice by 5–15%. Benefits of LLL from field trials in India and Vietnam are summarized in **Table 1**.

Table 1. Benefits and conversion factors of LLL.

Benefits	Percentage of benefits
Area increase when consolidating small fields into a large field	3–6[a,b,c]
Water savings	20–40[a,b]
Saving diesel fuel for pumping water	30-60[c,d]
Reduction of seed rate	40[c,d]
Saving fertilizer and pesticide	10–13[a, b, c, d]
Yield increase	5–15[a,b.c]
Reduce postharvest losses of rice produced	2–5[c]

*Lower values of the benefit ranges (%) were used to calculate this column

a = Jeetendra and Jat (2015), b = RKB (2020), c= Phan-Hieu-Hien et al. (2014), d = Tran-Van-Khanh et al. (2013)

Several demonstrations and trainings were conducted in the Philippines under WateRice Project. The field efficiency of laser-controlled land leveler was also determined in one atudy site and it varies from 36% - 72%. The field levelness accuracy of ±1 to ±2 cm was also attained. The leveling cost for every 1 cm difference in elevation per hectare was estimated at Php 758.31.

In a study that was conducted in Iloilo for a rainfed rice production, the yield increase reached up to 25% (Bautista et. al., 2020). The yield increase was attained with combined good weed and nutrient management.

3 Farm equipment required for LLL

3.1. Tractor

A four-wheel tractor is required to drag the scraper bucket. In Asia, widely used tractors ranging in size from 30 to 100 hp have been successfully used with laser-controlled systems. A tractor with higher capacity can haul a bigger scraper bucket and consequently generate higher efficiency of land leveling operations due to reduction in operating time and the number of no load runs in the field.

3.2. Plow

The field will require plowing before land leveling. It is often most economical to only plow the areas from where the soil will be removed rather than the whole field. Depending on the height of the soil that must be cut in the laser leveling operation, it may also be necessary to plow during the leveling operation once the loose plowed soil has been moved from the elevated areas and compressed soil appears at the surface. Disk plows (**Fig. 4**), moldboard plows, or tine plows can be used.

Fig. 4. Disk plow hooked-up to a tractor.

3.3. Scraper bucket

The leveling bucket or scraper bucket (**Fig. 5**) can be either be a three-point linkage mounted or pulled by the tractor's drawbar. Pull-type systems are preferred as it is easier to connect the tractor's hydraulic system to an external hydraulic cylinder than connect it to the internal control system used by the three-point-linkage system. Bucket dimensions and capacity will vary according to the available tractor power and field conditions. A 45-kW tractor is suitable to pull a 2-m wide x 1-m deep bucket in most soil types.

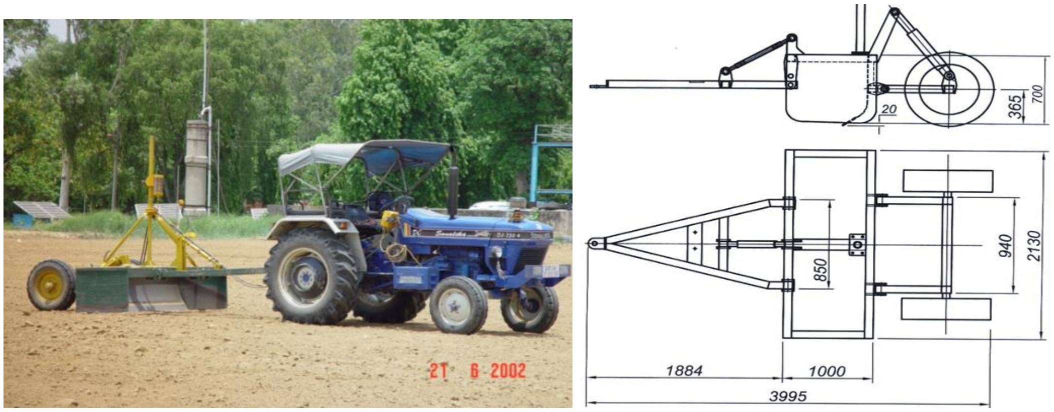


Fig. 5. Drag bucket matched with a 45-kW tractor.

Matching between the tractors and LLL system

The size of tractor in terms of horsepower (HP) should be properly matched with the size of the scraper bucket for more efficient and optimum field operations. The type of soil where the leveling operation is to be conducted should be considered in choosing the appropriate size of the tractor. A guide to tractor HP and scraper bucket size is shown in Table 2.

Table 2. Tractor horsepower and scraper bucket size matching.

Scraper size (operating width, m)	Tractor (HP)	
	Loam soil (lighter, dryer)	Clay soil (heavier)
1.5	50	60
2.0	70	80
3.0	100	120
4.0	135	160

When choosing the tractor and bucket size, there should be a systematic matching with the size of the hydraulic ram that is connected to the scraper bucket. The hydraulic ram should be appropriately-sized and strong enough to move the scraper bucket.

In considering the size of the scraper bucket, make sure that the width is enough to cover the rear wheels of the tractor. This is important in precisely moving the soil surface during the leveling operations.

It is also recommended to choose tractor that is heavier in weight and not just consider the available horsepower or higher kg/HP ratio. The downside with heavier tractor is higher fuel consumption but this is much stable and appropriate for leveling operations. For example, in Table 3 below, the Kubota tractor (L4508) is usually preferred and used in some countries in Asia but it is not suitable for LLL with 1.5m scraper bucket because of the lighter weight as compared to Belarus and John Deere, the most suitable tractor in for the 1.5m scraper bucket as shown in Table 3 is Belarus MTZ-52.

Table 3. Tractor weight to horsepower ratio of some common tractors in Asia.

Tractors	Kubota L4508, (4WD)	Belarus MTZ-50 (2WD)	Belarus MTZ-52 (4WD)	John Deere 5055 (4WD)
Engine power, HP	45.2	55	55	55
Weight: kg	1 415	2 850	3 220	2 410
kg/ HP	31.3	51.8	58.5	43.8

4 Laser control system

The laser control system consists of a laser transmitter, a laser receiver, an electrical control panel, and a hydraulic-control valve.

4.1. Laser transmitter, receiver, and control panel

The laser transmitter (**Fig. 6**) transmits a laser beam, which is intercepted by the laser receiver mounted on the leveling bucket. The control panel mounted on the tractor interprets the signal from the receiver and opens or closes the hydraulic control valve, which will raise or lower the bucket. See illustration below.

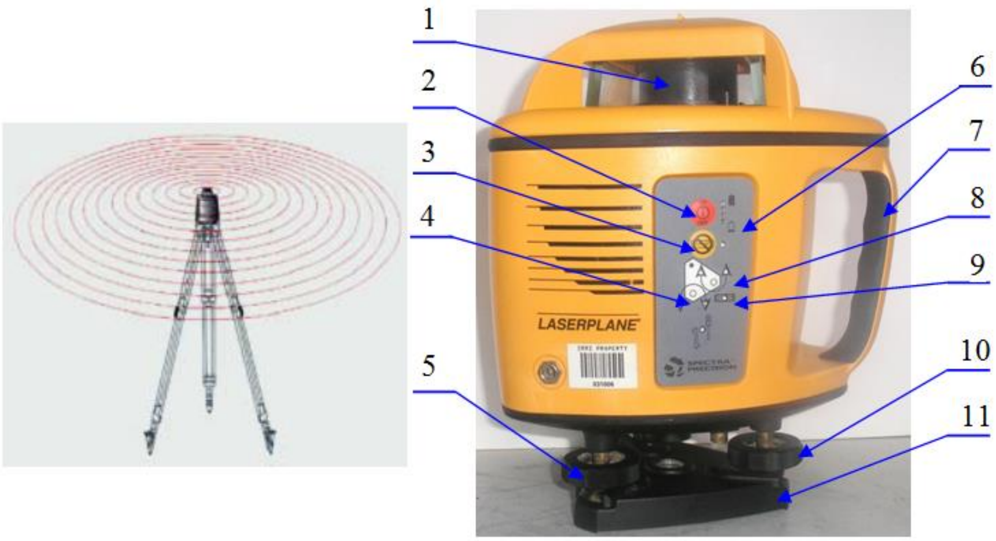


Fig. 6. Transmitter on a tripod creating a laser plane of light (left) and parts of a laser transmitter (right). Source: Laserplane (2020).

1 =l aser beam, 2 = on-off switch, 3 = functioning switch, 4 and 8 = unbalanced indicators, 5 and 10 = balancing switches, 6 = battery indicator, 7 = holding bar, 9 = balancing indicator, 11 = platform.

When the laser beam hits the laser receiver, which is mounted on the scraper bucket (**Fig. 7a**), two bands of sensors on the receivers' sides convert the relative height of the sensor to the laser plane into electrical signals, which are forwarded to and processed in the control box. The control box, in turn, sends corresponding electrical signals to solenoid valves of the hydraulic valve to control the oil flow as required to maintain the scraper bucket at the constant height.

For manually surveying the field, there also is a supplementary laser receiver (**Fig. 7b**) attached to a measuring rod that is used for the field survey before leveling and for checking the accuracy of the leveling operation after it has been completed.

Fig. 7a. Laser receiver mounted on the scraper bucket. Source: Trimble (2015).

Fig.7b. Supplementary laser receiver for field survey and accuracy evaluation. Source: Trimble (2015).

The control box of an LLL system (**Fig. 8**) is the main component that receives signals from the receiver and controls the solenoid valve. **Fig. 9** shows the scheme of a control box from a TRIMBLE laser equipment set with the following connections: 1) to the receiver (6-pin), 2) to the solenoid valve (10-pin), and 3) to the battery (4-pin, 10–30 VDC).

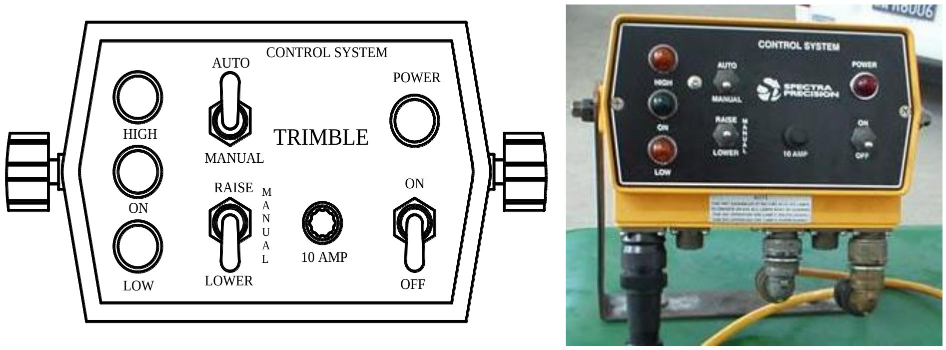


Fig. 8. The control box. Source: Trimble (2015).

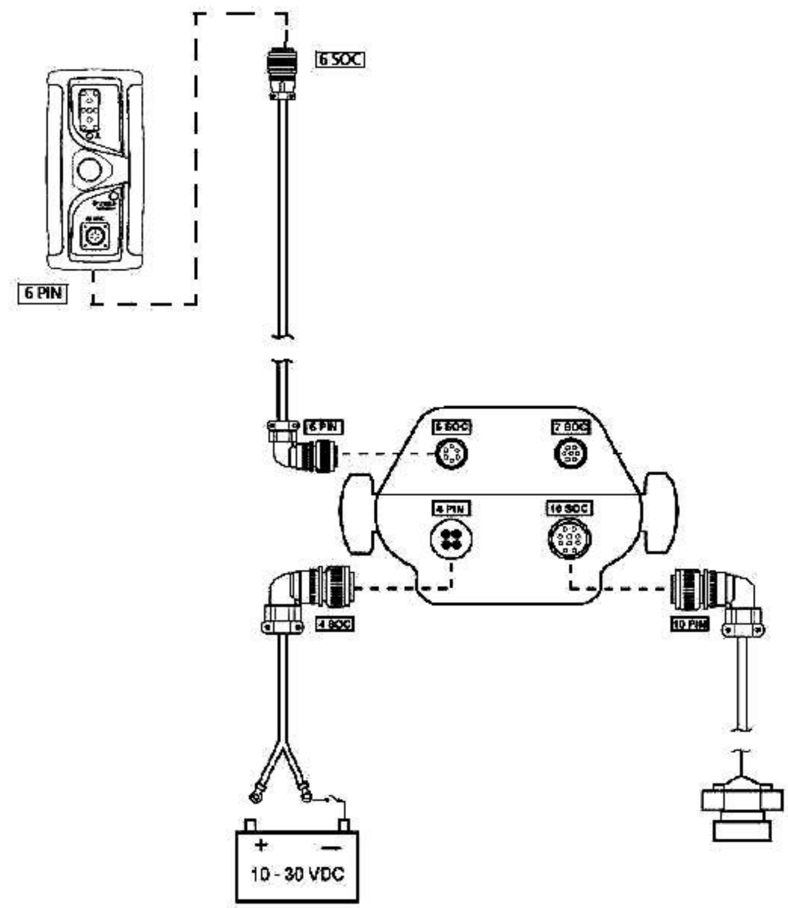


Fig. 9. Connection scheme of an LLL control box. Source: Trimble (2015).

4.2. Hydraulic control system

The hydraulic system of the tractor is used to supply oil for raising and lowering the leveling bucket. The oil supplied by the 36.8–58.8 kW (50–80 HP) tractor's hydraulic pump is normally delivered at 2,000–3,000 psi pressure for the LLL system. The hydraulic outlet of the tractor is connected to the hydraulic valve with the solenoid control valves, which is mounted on the scraper bucket. It controls the height of the scraper bucket through the hydraulic cylinder.

Fig. 10 shows the schematic diagram of a solenoid control valve with four ports and three positions (called Valve 4/3) to control the LLL hydraulic cylinder corresponding to three positions (too high, correct, and too low) of the scraper bucket (**Fig. 11a–c**). The control box will keep the scraper bucket always at the same height (correct position), resulting in the soil being scraped off and collected from the elevated areas of a field and getting dropped onto the low areas.

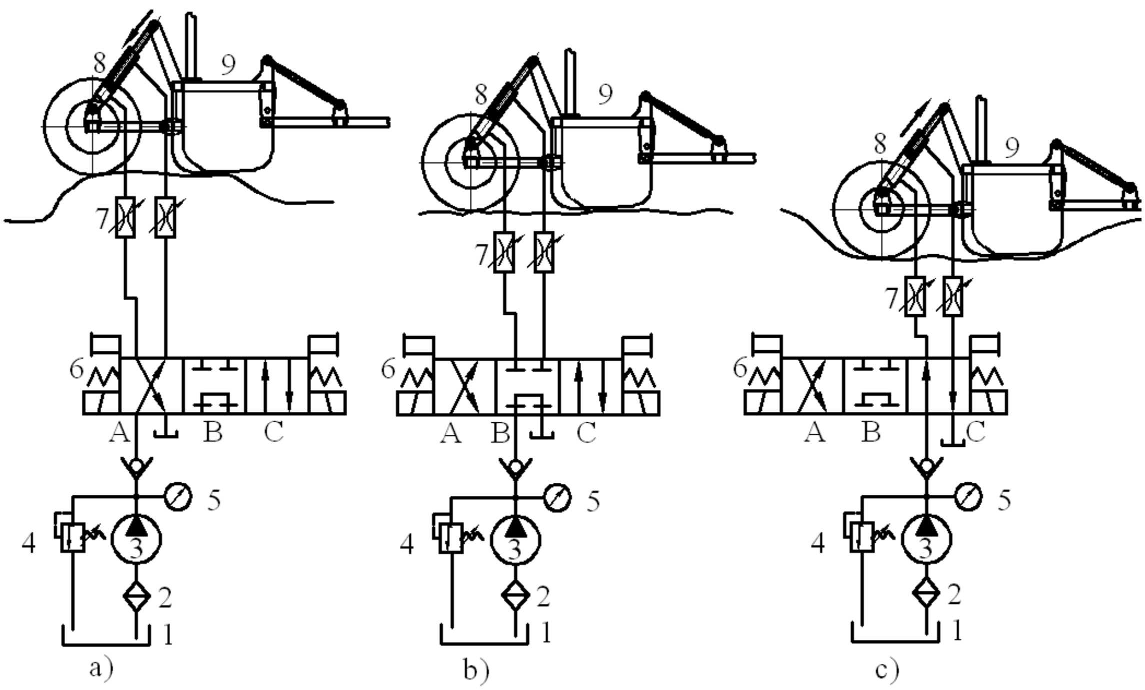


Fig. 10. Hydraulic system with a 4/3 valve to control the cylinder corresponding to three positions of the scraper: a) too high, b) correct height, and c) too low. Source: Hung and Nga (2015).

1 = oil tank, 2 = filter, 3 = pump, 4 = regulation valve, 5 = pressure gauge, 6 = solenoid valve, 7 = oil choke valve, 8 = hydraulic cylinder, 9 = scraper.

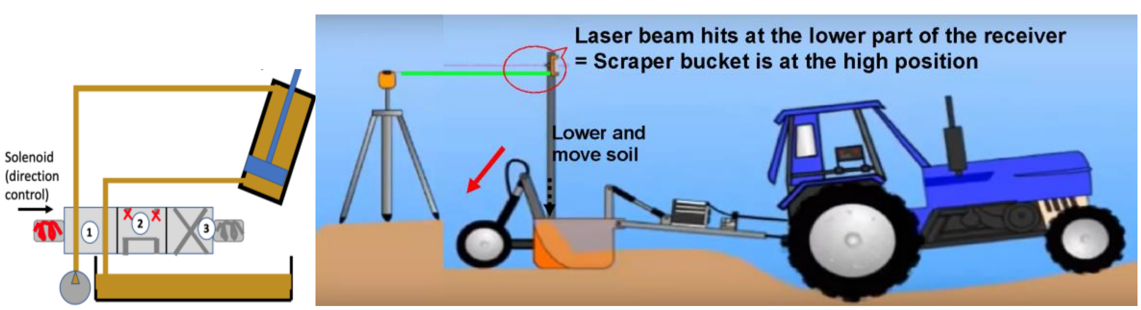


Fig. 11a. Scraper bucket at the "too high" position lowered to move soil (left) and the hydraulic valve activated scenario (right)

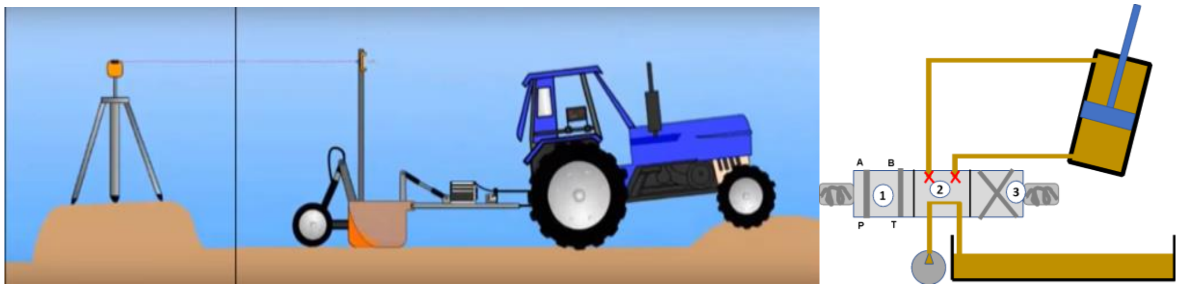


Fig. 11b. Scraper bucket at the mean "correct" reference height (left) and the hydraulic valve activated scenario (right)

Fig. 11c. Scraper bucket at the "too low" position raised to release soil (left) and the hydraulic valve activated scenario (right)

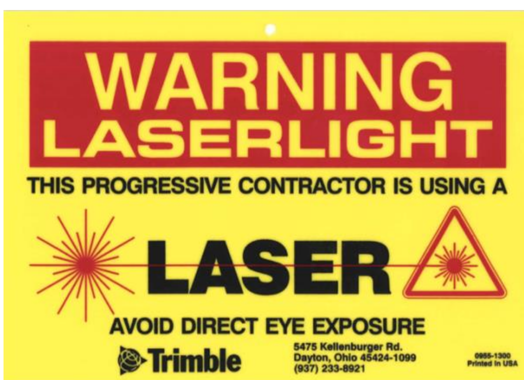
5 Conducting LLL

5.1. Operators' safety and minimizing impact on the environment

Farm mechanization generally makes a job easier but it also puts the operator and nearby people at risk when equipment is not carefully used and when it is not well maintained. Accidents can happen anytime at varying degree from minor ones, such as a rotovator hooked-up to a tractor running with blades loosely attached, to major incidents that involve serious bodily injury. Often the causes of accidents and injuries are ignorance of hazards and/or failure to recognize unsafe conditions by the operator, lack of understanding the principles of operation of the equipment, and poorly maintained machinery. A well-maintained machine can also reduce its environmental footprint through efficient operation and less fuel consumption.

To minimize risks to operators and bystanders:

- Follow standard workplace safety procedures for tractors and tractor implements;
- When manually adjusting the height of the laser receiver on the drag bucket, never do it while the tractor is moving;
- When working on the scraper bucket, make sure that the tractor is stationary, in neutral, and the scraper bucket is lowered to the ground;
- For the laser equipment (Trimble 2018)
  - Post at least one laser warning placard at each laser-controlled leveling location, thus:



  - Turn the laser off when it is not required or is left unattended for a substantial period of time;
  - Do not look directly into the laser or point the laser at another person;
  - Set the laser up well above the heads of employees when possible, otherwise set it up below;
  - For additional laser safety, refer to the documentation that comes with the equipment

To minimize impact on the environment:

- When working on the hydraulics, avoid spilling oil onto the soil;
- Optimize your leveling operation in order to maximize field efficiency for minimized fuel consumption.

5.2. Comparing land preparation with and without LLL

Table 4. Operations of land preparation and LLL service in the Philippines.

<table>
<tr><th>Operation</th><th>Land preparation without LLL</th><th>LLL + land preparation</th></tr>
<tr><td>Plowing (to loosen the soil for scraping ➔ leveling)
Note: Only once every 5 years</td><td>No</td><td>
Using the offset disk-plow machine (dry plowing)</td></tr>
<tr><td>Leveling
Note: Only once every 5 years</td><td>No</td><td>
Using LLL (dry levelling)</td></tr>
<tr><td>Plowing/ cultivation (using 2WT and 4WT-rotavator)
Note: Applied every season</td><td colspan="2">
Yes</td></tr>
<tr><td>Puddling and wet leveling
Note: Applied every season</td><td colspan="2">Yes</td></tr>
<tr><td>Bund building</td><td colspan="2">Yes</td></tr>
</table>

A comparison of land preparation with and without laser-controlled land leveling is shown in **Table 4**. An LLL service usually includes surveying, plowing, laser leveling, and surveying again to review the results.

This service needs to be conducted once every 5 years. Between LLL services, land preparation for every season includes rotavating the soil, puddling (or harrowing), and wet leveling (which entails flattening the soil surface with a plank attached to the puddling system).

LLL should be implemented based on the four steps shown in **Fig. 12** to increase its operational efficiency. The field surveying is necessary to make an accurate cost calculation before the service is offered to farmers.

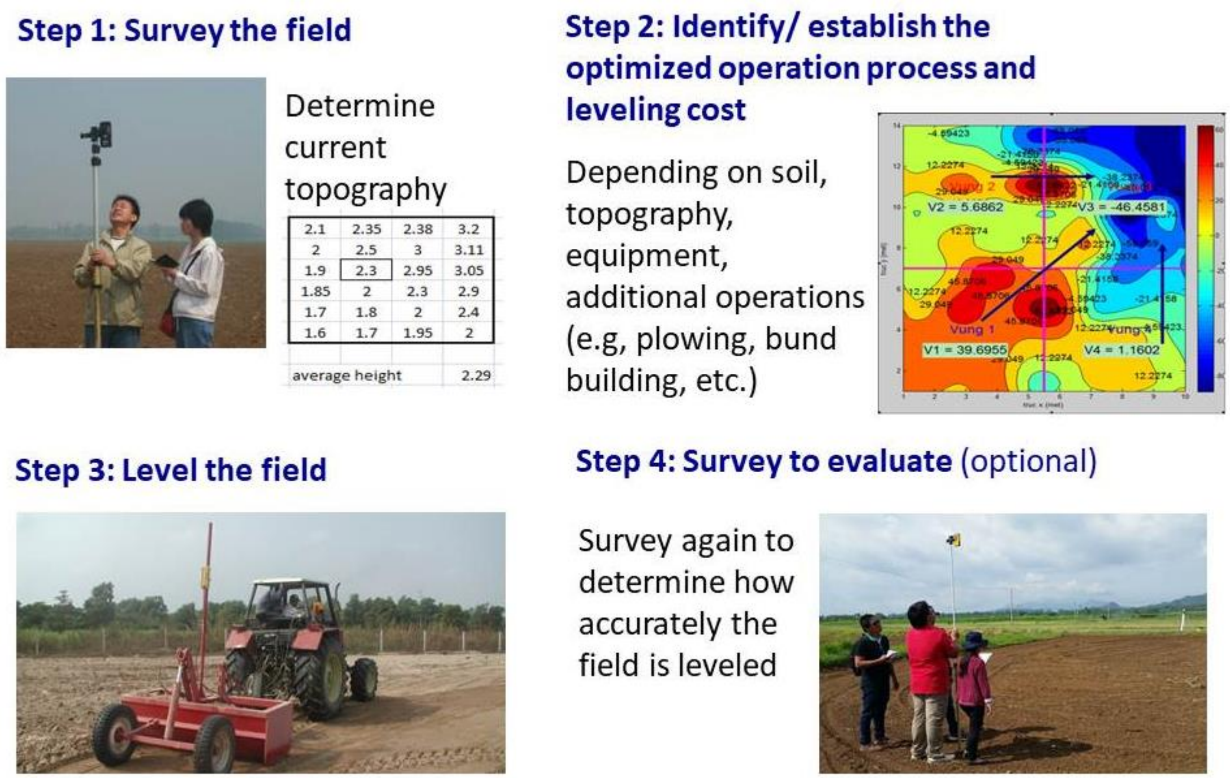


Fig. 12. Four steps of conducting LLL

5.3. Field surveying to determine the current topography

Fig. 13 shows equipment used for field surveying including a laser transmitter, a tripod, a measuring rod, and a small laser receiver.

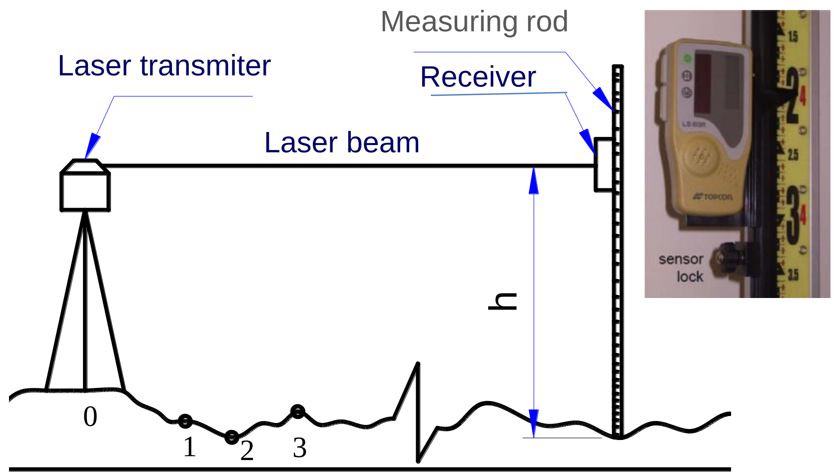


Fig. 13. Field survey with a laser transmitter, receiver, and measuring rod

The measurements can be set up based on the following steps:

- Set up the tripod on the side of the field at a location where no objects obstruct the view from the tripod to any location in the field.
- Set the tripod to a height that it matches the measuring rod's length when this is placed at any point in the field. Open the tripod legs and adjust the individual positioning of the legs until the base plate on top of the tripod is relatively leveled. Use the horizon as a visual guide to get the base plate leveled.
- Attach the laser transmitter to the base plate.

Field plan and measurements:

- Measure the plot or field size (note that the recordings can be taken up to a radius of up to 400 m from the transmitter).
- Measure the altitudes of different positions (**Fig. 14**). Distance of the adjacent points is about 10–20 m. An example of recording heights of the measured positions is shown in **Table 3**.

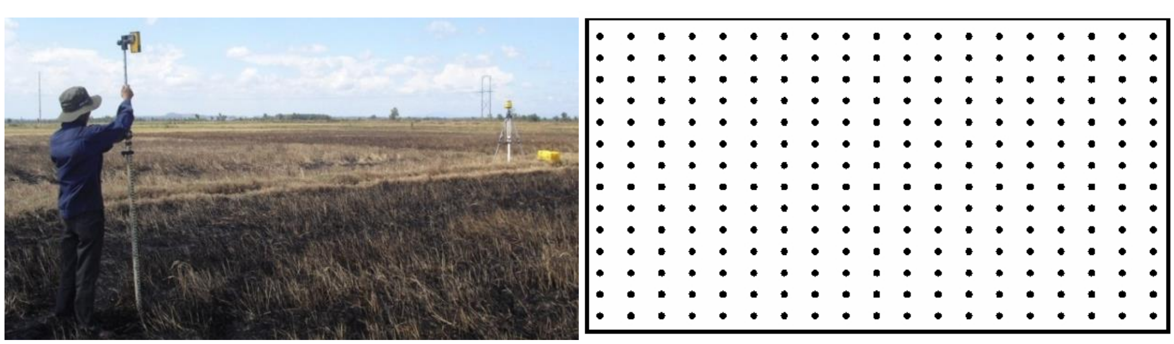


Fig. 14. A field plan and measurements

Table 5. Example of heights (m) measured in a field at different positions

2047	2047	2040	2057	2012	2012	2023	2028	2024	2033
2054	2054	2050	2051	2015	2015	2031	2034	2027	2012
2054	2054	2053	2051	2034	2034	2029	2033	2023	2007
2053	2053	2055	2051	2052	2052	2027	2031	2018	2001
2044	2044	2072	2052	2076	2076	1998	1991	1999	2001
2030	2030	2061	2062	2059	2059	2002	1979	1988	1986
2016	2016	2050	2073	2042	2042	2006	1968	1977	1972
2024	2024	2034	2016	2028	2028	2042	1974	1963	1976
2019	2019	2028	2017	2023	2023	2028	1952	1969	1953
2014	2014	2022	2018	2018	2018	2014	1930	1974	1929
2038	2038	2052	2036	2082	2082	2008	1982	1948	1932
2025	2025	2031	2018	2024	2024	1984	1967	1939	1943
2012	2012	2010	2000	1966	1966	1960	1953	1930	1954
2012	2012	2010	2000	1966	1966	1960	1953	1930	1954

Measuring distance in the field

It is important to be able to measure distance as many of the critical decisions that are made on a farm are based on being able to measure distance with some degree of accuracy. Calibration of equipment, determination of application rates, measurement of yield/unit area and speed of operation are a few variables that depend on distance measurement as input.

There are many ways to measure distance. The most common methods are using a tape measure or a calibrated step.

Tape measure

The tape measure is the most common instrument for measuring distance. Tapes can be made of steel, fiberglass, or plastic and vary in length from 1 to 200 m. Most discrepancies occur at change points where a tape length ends and then a new accumulative measurement is added. So, measured distances are more accurate when the tape is longer.

Calibrated step or pace factor

In some cases, it is not necessary to know the exact distance particularly when working in a huge area. Where errors of less than 5% are acceptable, distances can be measured by using a calibrated step or pace factor. Each individual will have different sized steps for different environmental conditions.

To determine each individual's pace factor, count the number of steps taken to walk a known distance in each environmental condition. This will vary according to the walking surface, the presence of obstacles, and the slope.

Determining the pace factor

- Mark out a distance of 100 m.
- Walk at normal speed and stride length over the measured 100-m course and count the number of steps.

- Repeat at least twice.
- Add up the total number of steps and divide by the total distance walked (see formula below).

The result is the pace factor with which you can determine the distance between two objects.

Pace factor = S distance divided by total number of steps

Example:

Marked distance on the field, S = 100 m;

Total number of steps taken to walk the 100 m distance,

Forward ⇒ 120 steps;

Going back ⇒ 124 steps

Average no. of steps = (120+124)/2 = 122

Pace factor = 100/122 = **0.82**

5.4. Evaluating the anticipated LLL operation

The anticipated LLL operation should be evaluated to optimize operation time and energy use and thus minimize cost for the end user. The evaluation should be conducted based on the following steps and from the data obtained from the topographic survey (see **Fig. 10**).

- Calculate the average height by adding up all the measured values and dividing them through the number of measurements:

  where h_m is the average height and h_i is heights of the measured positions

- Calculate the differences between the average heights and the height of any measured position in the surveyed field. The difference between h_i and h_m ($h_i - h_m$) is shown in **Table 6** (with the data from the example shown in Table 5). High and low positions are represented by the negative (-) and positive (+) values, respectively.

Table 6. Differences between high and low positions and average height

33	33	26	43	-2	-2	9	14	10	19
40	40	36	37	1	1	17	20	13	-2
40	40	39	37	20	20	15	19	9	-7
39	39	41	37	38	38	13	17	4	-13
30	30	58	38	62	62	-16	-23	-15	-13
16	16	47	48	45	45	-12	-35	-26	-28
2	2	36	59	28	28	-8	-46	-37	-42
10	10	20	2	14	14	28	-40	-51	-38
5	5	14	3	9	9	14	-62	-45	-61
0	0	8	4	4	4	0	-84	-40	-85
24	24	38	22	68	68	-6	-32	-66	-82
11	11	17	4	10	10	-30	-47	-75	-71
-2	-2	-4	-14	-48	-48	-54	-61	-84	-60
-2	-2	-4	-14	-48	-48	-54	-61	-84	-60

5.5. LLL operation

The optimal starting point in the field is one position of average height since this will be the final elevation of the leveled field. The tractor and scraper bucket are positioned at this point, the scraper bucket is dropped on the ground, and the laser receiver on the scraper bucket is then set in height so that is in the "correct height" position, meaning that, when the system is set on automatic mode, it keeps the scraper bucket in this position and neither tries to lift it or to drop it further.

To have an optimized LLL operation, the runs should be based on two rounds, the first for rough leveling and the second for finishing leveling.

- Rough leveling: Move the soil directly from the high to low positions (**Fig. 15**). At this stage, the operator can set the control box in "Manual mode" on the control box.
- Finishing leveling: For finishing leveling, LLL has to be operated automatically (using the Auto Control function on the control panel; see **Fig. 15**). It is advised to operate the tractor with the laser leveling bucket following the running contour of "center to side turning" as shown in **Fig. 16**.

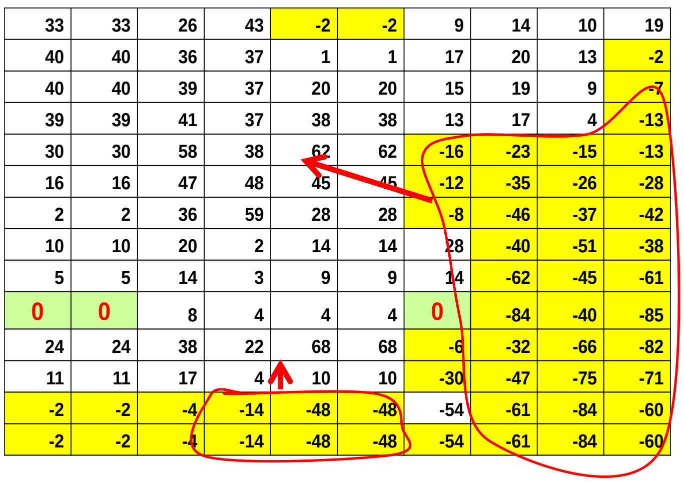


Fig. 15. Rough leveling process

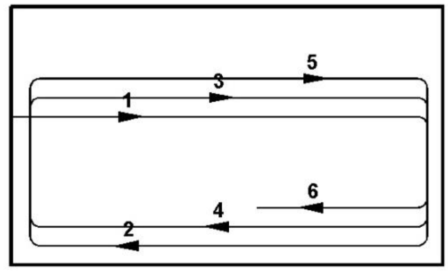


Fig. 16. Finishing leveling process

The time taken to level a field can be calculated by ascertaining the different physical parameters that describe the leveling process (**Table 7**).

Table 7. Parameters needed and steps to determine time taken to level a field

#	Parameter	Nomenclature	Method or equation	Unit
1	Plot area	S	Measured	m^2
2	Heights of measured positions	h_i	Measured by LLL (see section 2.4.1	m
3	Average heights of measured positions	h_m		m
4	Volume of soil to be moved	V		m^3
5	Volume of the scraper bucket	V_s	Measured	m^3
6	Number of LLL runs	n		
7	Average speed of the tractor (hauling LLL)		Measured (4–10 km/h)	km/h
8	Average length of a LLL run	L_{ll}	L_{ll} = 2*length of the plot	m
9	Time taken to level the field/ plot	t_{ll}	3 h for the field with its unevenness = 30–50 cm); e = 0.7 if tll>60)	h

5.6. Check the accuracy of leveling operations

It is good practice to check the accuracy of the field leveling operations by re-surveying the field. Surveying after leveling the field is usually done the same way as the initial surveying.

The level of precision for a laser leveled field should be 1–2 cm difference in height. A good rule of thumb is to have at least a 1-cm slope for every 100 m length on all sides of the field to aide irrigation and drainage.

5.7. Alternative options for surveying and checking the accuracy of leveling operations

This manual contains instructions for manually surveying a field. There are also automated options to do this, but they increase the price of the laser leveling system and, therefore, are often not considered for smallholder farmers in rice agriculture.

One option is a laser leveling system that has GPS functionality on board. This usually comes with software for mapping elevations. In this case, the tractor driver has only to drive in a systematic pattern through the field and the height measurements and map creation is done automatically. The system then also gives the starting point in the field for the leveling operation. Alternatively, separate GPS-guided systems can be used for automated surveys as shown in **Fig. 17**.

Fig. 17. Conducting field survey with a rover and an RTK base station.
(*Photo: courtesy of Thanach Songmethakrit*)

6 Checking and calibrating a laser transmitter

The laser transmitter should be periodically checked for accuracy. Most laser transmitters have two horizontal level adjustment screws that allow minor adjustments to be made along the two axes of the horizontal plane. The axes are usually labeled "X" and "Y" All checking and calibration procedures are done at the zero slope reading

6.1. Checking the transmitter

Items required to check the accuracy of the transmitter

- A suitable tripod that allows you to rotate the transmitter in 90 degree increments.
- A minimum 60-m range that is unobstructed and as close to flat as possible.
- A receiver on a measuring rod.

The check/calibration procedure is as follows:

- Mount the transmitter unit on a tripod at one end of the 60-m range and level it. Set X and Y-axes grade counters to zero. With auto leveling transmitters, turn the transmitter control switch to the AUTO position and wait for the Auto Mode Indicator Lamp to stop flashing.
- Station a rodman with a receiver mounted on the measuring rod at the other end of the range 60 m away.
- Align the laser, using the sighting scope or groove, such that the "X" is pointed directly at the rodman. Make sure the pentamirror is rotating and the Auto Mode Indicator Lamp has stopped flashing (if appropriate).
- Mark the reading as X1.
- Rotate the transmitter 180 degrees and wait at least 2 minutes for it to relevel. In non-auto leveling transmitters, manually relevel the transmitter.
- Have the rodman take another accurate reading and mark it down as X2.

Outcomes/results

If the difference between X1 and X2 is less than 6 mm, no adjustment is necessary and the laser can be assumed to give a correct reading.

If the difference is between 6 and 38 mm, the transmitter then needs to be calibrated and this can be done locally in the field. See Section 6.2 for how to calibrate the transmitter.

Note: If the difference is 38 mm or greater, the unit must be recalibrated at an authorized service center. You cannot recalibrate the unit in the field without damaging it.

6.2. Calibration of the laser transmitter

If the difference in transmitter readings is between 6 and 38 mm then the transmitter can be calibrated locally.

Procedure

1. From the two previous readings, calculate the “X” average = (X1 + X2)/2 and have the rodman adjust the receiver on the rod to the “X” average. Center the receiver between the two readings.
2. Locate the “X” calibration screw and adjust it to align the beam to the “X” average at the receiver. If gentle turning of the calibration screw cannot align the beam, return the unit to an authorized service center for calibration.
3. After adjusting the beam, allow for the unit to stabilize before taking the next reading, and then repeat the entire above procedure to check your work and do a fine readjust if necessary to get it just right.
4. After adjusting the “X” axis, rotate the transmitter 90 degrees to the “Y” axis. Point the “Y” axis directly at the rodman, using the sighting scope or groove and repeat the above steps. Call the readings Y1 and Y2 and calculate the “Y” axis average.

The same procedure may be employed by directing the beam onto a wall 60 m away. Instead of having the rodman recording on the staff, make a mark on the wall at X1 and X2 and then draw a line in the center. The beam is then adjusted until it is recorded at the centerline. This system is useful if there is no rodman available or a measuring staff is not available.

7 Financial analysis for a LLL system

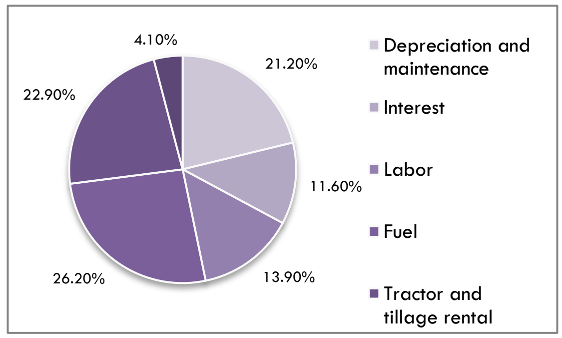
Table 8 shows an example of a financial analysis for an LLL business model in the Philippines. LLL cost components include depreciation, maintenance, interest, energy, labor, tractor rental, office, and taxes. Income is in the form of service fees for an LLL service provision. Profit is income minus costs.

Table 8. Sample financial analysis of a LLL business model in the Philippines

	Investment	Php
1	**Laser leveling system**	**800 000**
	Laser leveling system	800 000
	Tractor and implements	
2	**Warehouse for LLL**	**50 000**
	Total investment	**850 000**

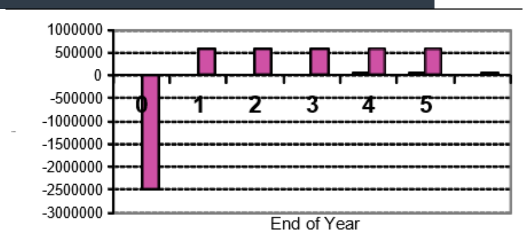
1	Depreciation	2 585
1	Life span of machine	7
2	Life span of workshop	10
3	Working time/day	8
4	Maintenance coefficient	1.3
5	Capacity (h/ha)	8
6	Working days/year	60
7	Capacity (ha/year)	60
8	Depreciation of LLL/year	114 286
9	Depreciation of workshop/year	5 000
10	Depreciation of LLL (Php/ha)	1 905
11	Depreciation of workshop (Php/ha)	83
12	Total depreciation (Php/ha)	1 988
13	**Depreciation + maintenance (Php/ha)**	**2 585**
2	**Interest (Php/ha)**	**1 417**
1	Bank loan (%/year)	10
2	Interest (Php/year)	85 000
3	Interest cost (Php/ha)	1 417
3	**Labor (Php/ha)**	**528**
1	Driver/Operator (Php/day)	500
2	Driver/Operator (Php/day)	500
3	Management (Php/day)	800
4	**Energy/fuel (Baht/ha)**	**3200**
1	Diesel price (Php/L)	40
2	Fuel consumption (Lit/ha) for the tractor 90 HP, uneven of field = 100-200	80
5	**Tractor and tillage rental**	**2 800**
1	Rental cost (Php/hr)	200
2	Rental cost (Php/ha)	1 600
3	Times of tillage	2
4	Tillage cost (Php/day/ha)	1 200
5	Tillage cost (Php/ha)	1 200
6	**Office cost (Php/ha)**	**500**
1	Phone, internet… (Php/month)	1 500
2	Logistics (Php/month)	1 000
	Total cost	
1	**Before tax**	**9 617**
2	**VAT (12%)**	**1 154**
	LL Contract service fee (Php/ha)	**15 000**

Total cost of LLL	(Php/ha)	%
Depreciation and maintenance	2 585	21.2
Interest	1 417	11.6
Labor	1 700	13.9
Fuel	3 200	26.2
Tractor and tillage rental	2 800	22.9
Office	500	4.1
Total	**12 201**	**100**



9	Payback Period
Income (Php/year)	900 000
LLL Cost (Php/year)	646 242
Net profit (Php/year)	253 758
Payback (years)	3.3

10	Internal Return rate (IRR)	
End of year	USD	Note
0	-850 000	Investment
1	253 758	Profit
2	253 758	
3	253 758	
4	253 758	
5	253 758	
IRR	**15.03**	



Figs. 18a and **b** show the net profit and payback period of an LLL service as a function of its annual capacity and service fee, respectively. The break-even point of the LLL-custom service business model is reached when the service capacity reaches approximately 70 ha/year resulting in a payback period of 3 years.

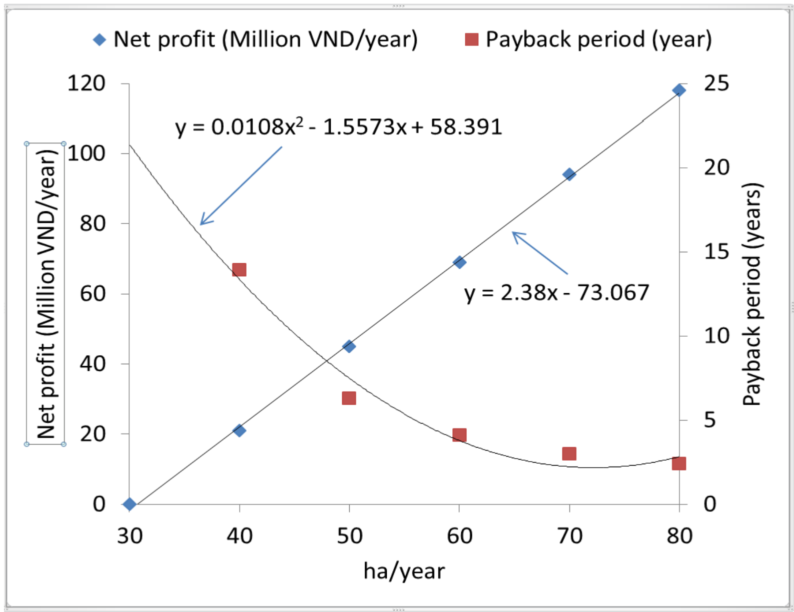


Fig. 18a. Net profit and payback period of LLL service by capacity

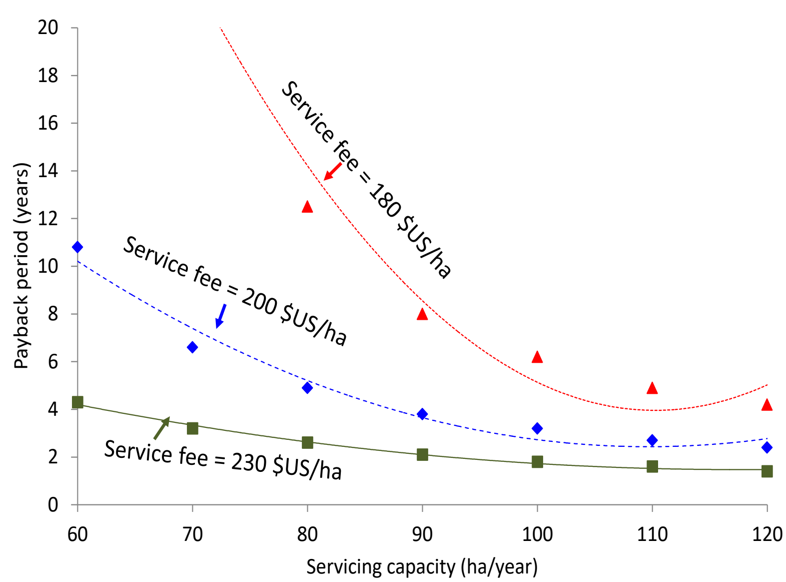


Fig. 18b. Payback period of LLL service for different service fees

8 Troubleshooting

If the laser leveling system does not work or produced unsatisfactory results, use **Table 9** to identify the root of the problem and potential solutions.

Table 9. Problems, causes, and potential solutions lower

Problem	Cause/solution
Bucket will not raise or lower	Check if the transmitter is working Check hydraulic connections Check electric connections on solenoid Check pressure relief valve setting on control valve Check for contamination in oil lines
Bucket doesn't respond in certain parts of field	Line of vision between transmitter and receiver is blocked Receiver is the same height as or lower than the tractor cabin Laser beam is above or below the receiver height
Bucket doesn't respond after several meters from the transmitter.	Operating under intense heat of the sun, the reach of the laser beam can be affected.
Bucket will only move in one direction	Check hydraulic connections Check electric connections on solenoid valves Check pressure relief valve setting on control valve Check for contamination in oil lines
Bucket shudders when first started	Oil is still cold Check pressure relief valve setting
Bucket raises and lowers in uncontrolled ways	Check line of vision Check electronic connections on solenoid Check oil level in tractor hydraulic system Check hydraulic valve of LLL
Field has uneven elevation after leveling	Traveling too fast Raising and lowering of scraper bucket is too slow
Field not level or create slopes in the field in the wrong way	Check and calibrate the transmitter is necessary Soil too compacted for bucket to cut
Soil not flowing out of bucket	Soil too wet and too much foreign matter in soil
Soil not flowing into bucket	Too much crop/weed residue on surface And/or soil too compacted
Areas filled with soil	Surface compaction during movement of soil was not uniform.

shrinks after irrigation	Make several rounds of the tractor during final leveling to ensure uniformity of surface compaction.
The hydraulic hose breaks	Hose specification is not enough to withstand the pressure from the hydraulic pump. Use hydraulic hose with the correct specification.

9 New developments in LLL

9.1. Modeling and optimization of LLL process

Optimizations of LLL operation were presented in recent studies, such as Mahdi et al (2014), Hung and Nga (2015), and Hung et al. (2016). **Fig. 19** shows interface of a tool for LLL optimization (Hung et al (2010).

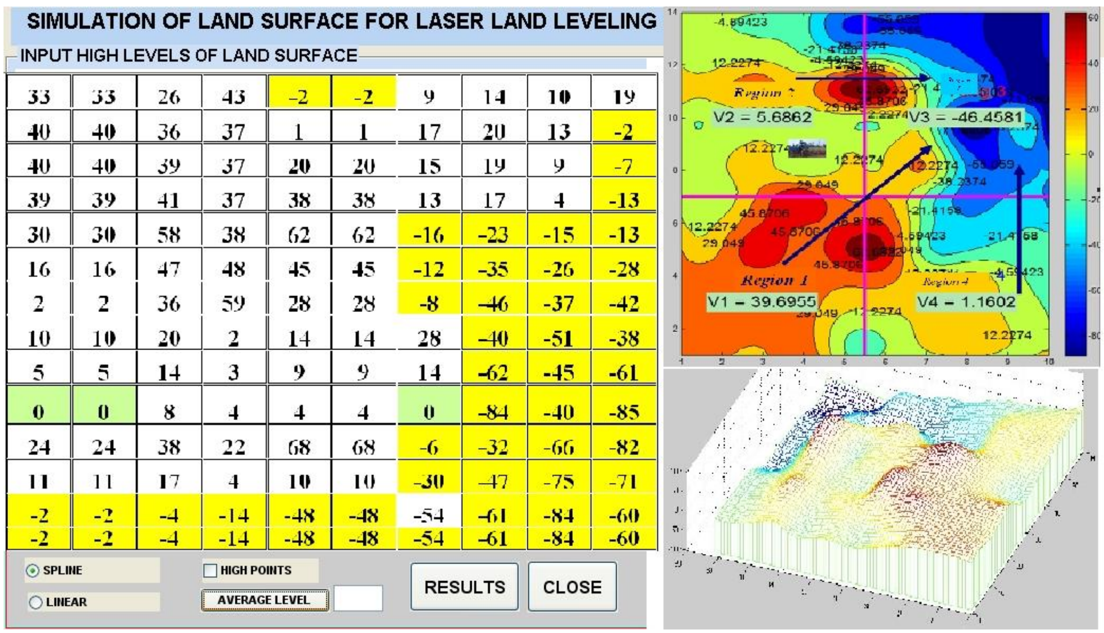


Fig. 19. Simulation of land leveling process (Hung et al 2010)

9.2. Using drones and GIS for land leveling surveying

Use of drones and GIS in land leveling surveying are offered by many companies, such as Wingtra (https://wingtra.com/drone-mapping-applications/surveying-gis/) and Dronelife (https://dronelife.com/2016/02/02/land-surveying-with-drones-an-expert-discussion-part-2/). These technologies can generate 3D-maps and the 3-D dimensions, slope, and contour (**Fig. 20**) of the field.

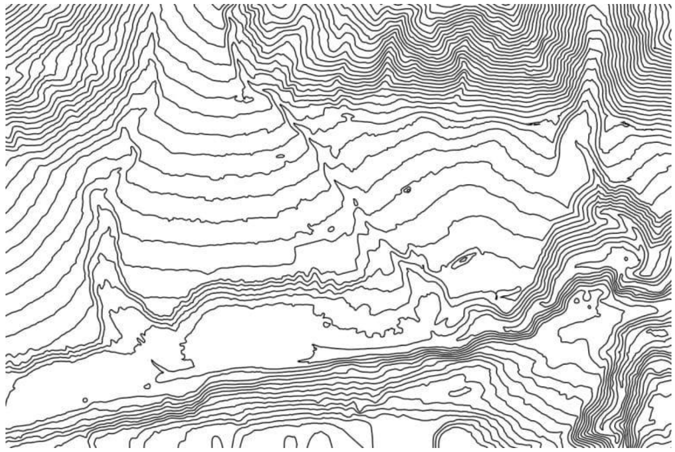


Fig. 20. Field contour map captured using a drone

Constraints, gaps, lessons learn and recommendations for adopting LLL in the Philippines

IRRI's Mechanization and Postharvest Cluster spearheaded a roundtable discussion on laser land leveling to share experiences from different stakeholders, gather feedback from end-users on the adoption of the technology. It also aims to develop a strategy to create opportunities for knowledge and information sharing and to draft next steps for further dissemination of the technology in the country through collaborative projects implemented by IRRI and national agencies such as WateRice and RiceStrawPH projects which are funded by the Philippine Department of Agriculture.

Representative from different institutions, including IRRI, participated in the exercise in identifying challenges, gaps, constraints encountered, development intervention needed, and support needed. A word frequency analysis which displays the most frequent response articulated during the discussion was also done (see Figure 21-23). In Figure 21, the most frequently mentioned challenge was "behavior" which pertains to farmers' behavior (traditional mindset and "to see is to believe," risk aversion attitude, complacency) and "knowledge" pertaining to knowledge gap in terms of the technology, understanding of important principles on soil movement and fertility.

Figure 21. Challenges, gaps and constraints on the laser leveling adoption in the Philippines.

Figure 21 refers to the word cloud as a visualization of frequently-mentioned words when asked about the development interventions needed to address the challenges. Participants identified important holistic development interventions such as enabling custom service provision to individual farmers, interventions that drives changing views on adoption of technology, and development of low- cost laser leveling system. Another most frequently mentioned interventions are training and educating key stakeholders that would be more meaningful than just providing training. Funding is another important intervention that comes along with efficient contracting services, creating information campaigns to raise awareness, and fostering partnerships among different sectors.

Figure 22: Word cloud for the responses related to “development interventions needed” to scale up the laser leveling initiatives in the Philippines.

Figure 23 refers to the word cloud that is associated to the responses related to “support needed.” Most frequently mentioned words were support (government subsidies, tax subsidies that will favor procurement of LLL system, financial/budgetary support, policies support that enables land consolidation and related law enforcement), services (contract services, after sales services) and training to ensure that the use of equipment, its maintenance, and service will be optimized.

Figure 23. Responses to 'development support' needed.

Thailand

The LLL technology was introduced in Thailand in 2014 through training in the northern part that was facilitated by Joseph Rickman of IRRI-Thailand Office, it was participated by staff of Trimble's local distributor and Thai Rice Department. It was in the same year that Crop Tech Asia (CTA), a local distributor of Trimble products started a custom service provision business model and was able to level around 28 hectares on the same year. In 2015, two staff from the Rice Department attended a 4-day training on Laser Land Leveling at IRRI-HQ that was supported by CORIGAP Project and in 2016 the CORIGAP project established a demonstration farm at farmers' fields in Chainat (6.4 has.) and in Nakhonsawan (5.6 has.). Related projects of the Rice Department such as the Megafarm adopted the technology and purchased one unit of LLL from CTA. During the CORIGAP Pro phase there was a consistent effort in the dissemination of the technology such as conduct of field demonstrations, adaptive trial on LLL as well as conduct of trainers training in Chainat on May 28-31, 2019. This was complemented by the support of IRRI in the development and the approval of a GIZ-funded Thai Rice NAMA project targeted for implementation from 2018-2022 which furthered the promotion of business models on laser leveling custom service provision.

The success towards wider adoption and dissemination of the LLL technology in Thailand would owe to the consistent intervention and harmonious collaboration among different institutions that involves the public-private and non-government institutions (Rice Department-Trimble/CTA-IRRI-GIZ). The appropriate interplay of the technical, economic and social dimensions of technology dissemination and adoption would provide proper education and appreciation to a wide range of stakeholders and end-users.

Myanmar

The laser-assisted land leveling technology was introduced in Myanmar way back in 2006 through the Irrigated Rice Research Consortium (IRRC) where initial demonstration was made. Since then, isolated testing and actual leveling of farmers' fields were done but was not sustained due to lack of support from the public and private sector and the IRRC project also ended. The interest on the technology still remained with the farmers as it came out in a Learning Alliance meeting to be included in the Diversification and intensification of rice-based systems in lower Myanmar (MyRice) and the Closing the Rice Yield Gap projects which are funded by Australian Center for International Agricultural Research (ACIAR) and the Swiss Agency for Development and Cooperation (SDC), respectively. These projects saw the need of scaling-out the technology at the farmers' fields to achieve higher productivity, sustainability of rice production and ensure environmental preservation through savings in water, increase in yield, efficiency in the use of agronomic inputs and better efficiency in field operations.

The projects then supported attendance to a laser leveling training of three (3) local staff at IRRI-HQ to learn about basic operation, setting-up, maintenance and trouble-shooting of the equipment. The LL system in Myanmar was also restored along with the fabrication of a drag bucket. Farmers' got excited and provided support by lending a 4 wheel drive tractor and implements for field testing and demonstrations. On March 21, 2017 a successful demonstration at a farmer's field in Maubin was attended by farmers, extension agents, government and private sectors. IRRI's private sector partner, Trimble, is keener in supporting the dissemination of the laser leveling technology in Myanmar by making it available for testing, distribution and support services. A new laser leveling system unit was donated by Trimble through IRRI to be used for further adaptive testing and demonstration of the technology at the farmers' fields.

Led by the Postharvest and Mechanization Unit of IRRI and Trimble in collaboration with MyRice and CORIGAP projects, a roundtable discussion was conducted on 6 October 2017 to further explore possibilities and options for the successful dissemination of the technology in Myanmar.

The Agricultural Mechanization Division (AMD) has included the activity on laser land leveling in the current implementation of Agricultural Development Support Project (ADSP) where trainings and demonstration of the technology have been conducted in Yezin, Naypyitaw.

Indonesia

The Closing the Rice Yield Gap Project (CORIGAP) has introduced the LLL technology in Palembang, South Sumatra through conduct of trainings, demonstrations and adaptive field trials at farmers field since 2016.

Our active partners from Badan Litbang Pertanian (BPTP) or the Indonesian Agency for Agricultural Research and Development (IAARD) in South Sumatra have conducted several field trials to compare advantages of a laser leveled field and traditionally-leveled field that is planted to rice and corn.

Table 10. Summary of lessons learned and recommendations.

Specific area	Problems encountered	Recommendations
Soil type	Rain occurrence a day before leveling operations, hence, wetting the soil.	Loamy sand soil, drain easily drains especially if its windy and sunny during the day, levelling can be done in the afternoon (as in Chainat, Thailand) For heavy clay soils, it takes more than two (2) days to drain the water and excess

		moisture from the soil to be able to conduct levelling (as experienced in S. Sumatra, Indonesia and Letpadan, Myanmar)
Bucket fabrication	Bracket supports and metal scrapers bucket break during levelling operations	Ensure quality fabrication by full welding of the scraper bucket members as well as the supporting bracket during local fabrication. Spot welding is weak and will lead to interruptions during operation with breakage of the scraper bucket (as experienced in Indonesia and Myanmar)
Control box	Wrong cable connection to the terminal of the control box to solenoid will not move the bucket up or down.	Check properly the cables and terminals on the control box that that go to different connections such as the solenoid, battery (for power) and laser receiver to ensure proper functioning of the system (as experienced in Indonesia).
Tractor size (hp)	Use of small tractor HP (≤50HP) to carry 2m wide bucket won't move the bucket when filled with soil (as experienced in Indonesia).	Match appropriate tractor power with bucket size to ensure smooth operations, a 2m wide scraper bucket will need at leasy 60HP 4WD tractor.

10 Review questions

- What are four reasons for leveling land for rice production?
- How many m^3 of soil is equivalent to 1cm/ha?
- What is field efficiency?
- What can be done to maximize field efficiency of LLL?
- What is the expected cost of land leveling 1 ha using a laser control system for 1 cm change in elevation using a 40-kW tractor?
- How long will it take to level a field with 8 cm variation using a 40 kW tractor and laser leveler?
- How do you establish the mean elevation height of the field?
- How much slope should you aim for in a field after leveling?
- When should you send the laser transmitter to the dealer for recalibration?
- How to calibrate a laser transmitter in the field?
- How many steps will you take to measure 100 m in distance?
- What advice would you give a farmer after leveling his or her land?

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