Chapter 6

Mechanization of transplanting shrubs seedlings and contours laser guiding for Vallerani system

Chapter 6: Mechanization of transplanting shrubs seedlings and contours laser guiding for Vallerani system

I. Gammo and T. Oweis

6.1 Introducing a mechanized transplanting option to the WH system

6.1.1 Introduction

Many water harvesting (WH) technologies have been successfully tested over many years, including such techniques as small-scale WH with contour furrows and microcatchments of different shapes and sizes (Hatten and Taimeh 2001). The mechanization of WH using the Vallerani implement has been evaluated in the Badia ecosystem. Drought-tolerant forage shrubs (Gammoh and Oweis, 2011)(most commonly *Atriplex spp*) have been successfully established under these WH systems. Nevertheless, the establishment of forage shrubs has encountered problems associated with the following:

Shrub establishment techniques use transplants > 6 months old. This increases the cost of their nursery, transport, field preparation, and planting, as augering 40 cm × 40 cm × 40 cm holes is required. A lot of manual work and time is required, and if rainfall is delayed, then plants need supplemental irrigation to survive until the first effective rain. The survival rate of such transplants in dry seasons might drop to 60–70% (Abu Zanat 1995).

Direct seeding has problems related either to soil crusting/silt sedimentation resulting in high emergence resistance or to reducing the ability of young emerged seedlings to survive through dry periods to the next rain.

The large-scale implementation of WH systems is slow and costly, as the system is not fully mechanized. Some establishment operations still depend on manual work due to the absence of specialized machinery for WH techniques.

6.1.2 Objectives and expected outputs

In relevance to the project objectives and expected outputs, the reported research aimed at introducing a mechanized transplanting technique to the WH system to reduce costs and time of establishment of fodder shrubs, thus improving overall system capacity and making large-scale implementation more feasible. Therefore, the expected output is to improve WH and re-vegetation techniques with less cost and time of establishment for fodder shrubs.

The specific objectives of the research work presented here are:
To study the feasibility of establishment of *Atriplex* plants of young (1–2–month-old) seedlings instead of > 6-month-old plants.
To determine the best conditions under which the transplanting technique will be most successful. This includes: (a) time of transplanting, (b) placement of the seedling inside the WH catchment, and (c) the water regime to support the plants expressed in the volume of harvested water (i.e. length of the runoff area).

To modify the traditional transplanter unit to cope with the specific structure of the WH furrow (planting the inclined shape of the furrow ridge), and attach this unit to a plow so that the opening of the furrow and transplanting of the seedlings are performed in one pass of the tractor.

6.1.3 Methodologies and approaches

The work was divided into two stages: the first involved the first two objectives mentioned above, while the second concerned the modification of the transplanter.

In the first stage a field experiment was designed and implemented in the 2006/07 rainy season.

Site conditions and plant material

The chosen site for this experiment was inside the University of Jordan (UOJ) Research Station in Muwaqqar; 400 m above sea level, and located 30 km south east of Amman. The coordinates are 266o-270 o East, 130 o -135 o North (Royal Geographic Center plate No NH37-A-1). Good facilities and more protection of the sites are provided there for monitoring and control. The site is representative of the arid region of Jordan (the Badia), where annual rainfall average is 100–150 mm.

The WH structure was prepared in the first week of December 2006. The area of the experiment was around 0.8 ha with a uniform slope of 3–4%.

The catchments are continuous tied furrows worked by Vallerani plow that made a wide (> 50 cm) and deep (> 30 cm) cut with a ridge of ~ 50 cm height from the bottom of the furrow.

In specially fabricated trays, 1000 *Atriplex* seedlings were grown from seeds at three different dates (one month before transplanting date). Each tray consisted of 100 pots, and each pot was cubic with dimensions of 4 cm × 4 cm × 4 cm.

Exactly 864 seedlings were chosen to be planted 1 m apart inside the catchments. Each plot catchment had a length of 24 m; 12 seedlings were planted in the bottom of the catchment and 12 on the bottom 1/3 of the ridge. Transplanting was done manually.

Treatments and experimental design

a) Main treatments (reflect time ofplanting)

T1: Transplanting before first rainfall. This is the common practice followed, aimed at getting the benefit from every rainfall event in the season. However, as the time of the first rain is not known, there is a risk of young seedlings wilting unless watered regularly. This treatment was performed on 24 December 2006 and, fortunately, the first rainfall was 3.4 mm on 26 December 2006, followed by 27 mm on 27 December 2006.

T2: Transplanting few days after a good runoff event, and when soil is workable. This ensures sufficient moisture in the soil from previous rain events for use by plants. There is no need to support young seedlings with water to the next rain. This treatment was performed on 28 January 2007 after a rainy week of 19 mm of rainfall and a good runoff event (11 mm) on 21 January 2007.

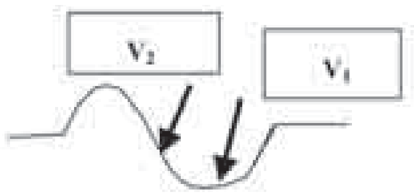
T3: Transplanting in spring at the beginning of the warm season. The speed of growth in warm conditions should enable young plants to develop their roots quickly to the safe wet soil layer before the top soil dries out. Any rain that occurs later will give even more benefit. This treatment was performed on 11 March 2007. The total rain that fell after this date until the end of March 2007 was 26 mm, of this 13 mm on 15 March 2007 initiated one effective runoff event.

b) Sub-treatments (reflect harvested water regime)

t1: 4 m – length of harvesting area
t2: 8 m – length of runoff area
t3: 12 m – length of runoff area

c) Split variables (reflect placement of plant inside the furrow)
V1: Transplanting in the bottom of the furrow close to the ridge (wetter).
V2: Transplanting above the bottom 1/3 of the ridge (less sediment).

Experimental design was chosen to be split RCBD in 4 replicates.



Parameters assessed

Survival percentage through survival count, was assessed monthly until the end of dry season.

Estimated volume of the plant, by measuring the height and width of each plant at the end of the growing season, then calculating the volume using the mathematical equations of the volume of either a cylinder or a cone, depending on the shape the plant developed during growth. A cylindrical shape was usually developed by plants of one or two longitudinal shoots, and of less than 10 cm width. Volume given by V_{cyl}:

$$V_{cyl} = \pi r^2 l$$

where r is cylinder base radius and l is cylinder height Inverted cone shape for plants of ≥ 3 shoots and of > 10 cm upper part width. Volume given by V_{cone}:

$$v_{cyl} = \pi r^{-} l$$

where b is cone base diameter and a is cone height.
The plant volume was calculated for each surviving plant and then average plant volume of each plot was calculated for surviving plants only, where the average plant volume in a plot was equal to the sum of plant volumes over the number of survived plants in that plot.

Although it is more common to use biomass as a parameter of plant productivity under different treatments and variables, it was thought that assessing plant volume would be adequate for this purpose for the following reasons:

By the end of the growing season, the plants will be still young and not mature enough to be grazable
The plants will be monitored and evaluated for > 1 year;, therefore non-destructive methods of assessing biomass should be followed

Transplanter modification

Instead of building a special transplanter, it was decided to modify a traditional one as used to plant other seedlings (e.g. tomato, sweet pepper, and lettuce) to perform the transplanting under the WH structure conditions and requirements. The modifications included:

- Changing the slot-opening device with the local fabricated one that can work deeper than the depth-wheel adjustment permits, as the slot should be opened in the inclined ridge of the catchment at below natural ground level.
- Adding protecting boards to the slot opener to prevent soil from falling down from the ridge over the seedling before it rests inside the slot.
- Reducing the distance between the slot opener and the covering wheels to a minimum.
- Changing the adjustment range of the depth-wheel design so it can be raised higher. This allowed the unit to go deeper.
- Adding a covering disc to improve the seedling soil pot covering.
- Changing the pressing device design and location on the transplanter and

lowering the left pressing wheel to contact the lower side of the ridge.

- Changing the hitching system of the transplanter so it can be hitched to a regular square-section tool bar. This included the fabrication of new brackets and clamps.

The modified transplanting unit was attached to a WH furrow-opening plow (designed previously at UOJ). The new integrated furrow opener and transplanting unit were able to open a continuous deep furrow and transplant *Atriplex* seedlings inside the furrow in one pass of the tractor. This dramatically reduced the amount of work usually needed to open WH furrows and plant *Atriplex* in them.

6.1.4 Results and discussion

Survival percentage

The survival percentage was monitored nearly every month, through the growing and dry seasons, to detect changes under different treatments and sub-treatments. The targeted readings are considered those obtained after that period, which were taken on 9 September 2007, therefore the statistical analysis was performed only for those readings.

Establishment of *Atriplex* by transplanting young seedlings could be successful. The percentage of surviving plants through the growing and following dry seasons (calculated on 9 September 2007; Table 6.1) had range 37–80% (for T_1 and T_2, respectively). This clearly justifies the adoption of such a technique, instead of the costly (labor and time consuming) use of six-month-old *Atriplex* plants. Moreover, such a result indicates the success of mechanizing the transplanting technique.

Although the planting before the rainy season (T1) was expected to give best results, it showed the least survival percentage. This could be attributed to freezing weather that struck in January 2007, when the minimum temperature ranged from –2 to –4°C for 3 d during 1–3 January 2007, and from –1 to –3°C for 8 d during 13–20 January 2007.

Table 6.1. Survival percentages under different treatments, sub-treatments, and split variables by the end of the dry season.

Survival Percentage on 9 Sept 2007									
Date of planting	**T_1 = 24 Dec 2006**			**T_2 = 28 Jan 2007**			**T_3 = 11 Mar 2007**		
Spacing	t_1=4 m	t_2= 8 m	t_3=12 m	t_1=4 m	t_2=8 m	t_3=12 m	t_1=4 m	t_2=8 m	t_3=12 m
Placement V_1	35.4 fg	33.3 fg	37.5 e–g	79.2 ab	81.3 ab	75.0 a–c	39.6 dg	79.2 ab	54.2 b–f
Placement V_2	35.4 fg	39.6 d–f	41.7 c–f	91.7 a	72.9 a–d	81.3 ab	64.6 a–cef	70.8 a–ce	58.3 a–f
Average treatment	T_1 = 37.2 B			T_2 = 80.2 A			T_3 = 61.1 AB		
Average spacing	t_1 = 57.6 A			t_2 = 62.9 A			t_3 = 58.0 A		
Average placement	V_1 = 57.2 A V_2 = 61.8 A								

Note: LSD values for treatments, sub-treatments, split variables, and their interaction were 30.4, 12.6, 7.7, and 32, respectively.

Starting from 16 March 2007 the decrease in survival percentage was the greatest (39%) under T_3 (transplanting in spring), the least (13.5%) under T_2 (transplanting few days after first good runoff event), and 24% under T_1 (transplanting before the season). The large drop in survival rate under T_3 could be attributed to the inability of some young seedlings planted in spring to develop roots deep enough to reach the wet zone before the top soil dried out. The survival percentage, in general, was clearly not affected by the spacing between furrows (length of runoff area) (Figure 6.1). The furrow spacing had a significant effect on soil water storage in relatively deep layers, which the young seedlings' roots had not reached yet at this growth stage. Furrow spacing is expected to have an effect under conditions of higher annual rainfall and higher intensities of rainfall events that initiate runoff.

The seedling placement inside the catchment had no significant effect on the survival percentage throughout the growing season and the following dry season

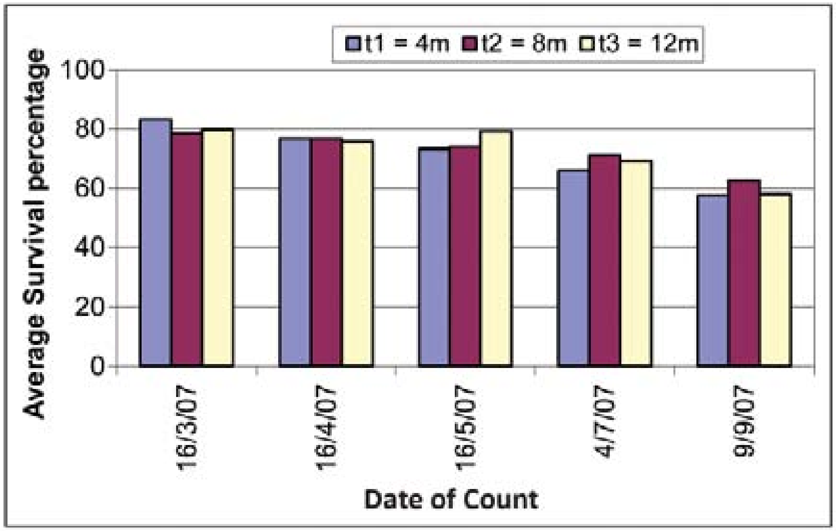


Figure 6.1. Effect of furrow spacing on survival through the dry season.

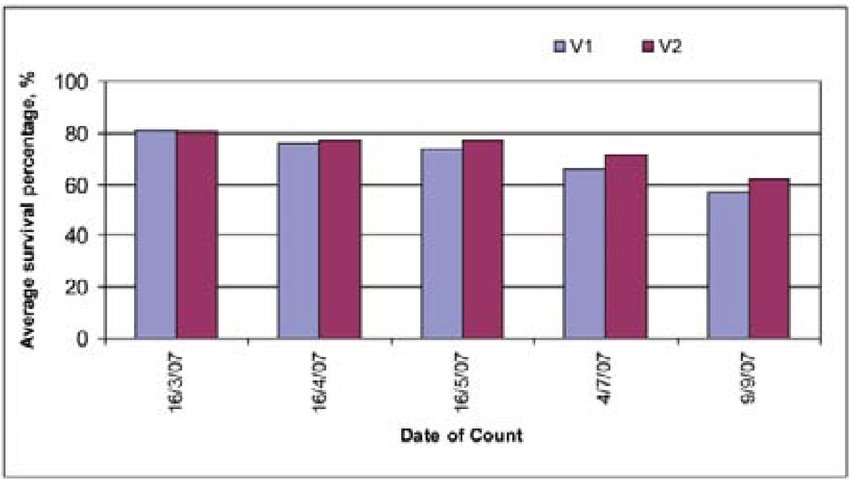


Figure 6.2. Effect of plant placement inside the catchment on survival through the dry season.

(Figure 6.2). Nevertheless, when drought stress increased from June onward, the drop in survival percentages for V_2 and V_1 were 19 and 23%, respectively, showing an advantage to V_2.

Average plant volume

- Planting before the first rainfall (T_1) proved to have the best effect on plant growth; although the survival rate for these plants was less than for plants planted after the first good rainfall with runoff (T_2). The survived plants that were planted one month before (T_1) seem to have benefited from rainfall between the two dates of planting.
- Average plant volume under T_3 (planting in spring) was the lowest, although the plants' survival percentage was better than for T_1. This can be attributed to the fact that plants could not develop their roots fast enough to reach deeper soil layers before the top soil dried out.
- There was no significant effect of the length of runoff area (t1 = 4 m, t2 = 8 m, and t3 = 12 m) on the plant volume under relatively low rainfall intensities and moderate slopes. The difference in the volume of water harvested from different runoff areas would be expected to affect the water regime in the catchment under conditions of high rainfall intensities and steeper slopes.
- The overall average plant volume when planted in the bottom 1/3 of the ridge (V2) was 537 cm^3 (Table 6.2) compared to 296 cm^3 when planted in the bottom of the furrow (V1). This can be attributed to the looser soil and deeper root development in the root zone on the ridge, which was more protected than soil in the bottom of the furrow.

6.1.5 Conclusions

Transplanting young seedlings (1–2 months old) was successful for establishment of forage shrubs in marginal rangelands or steppe regions (the Badia) under WH systems. This practice can substitute the traditional practice of using transplants aged > 6 months.
The benefits obtained from this modified technique are:

a. Ease of mechanization of planting, as the small size of young seedlings makes handling by the transplanter possible. This excludes augering and manual digging operations usually needed when planting older transplants in WH structures.
b. Faster operation, especially when large-scale implementation is needed.

Table 6.2. Average plant volumes (cm^3) under different treatments, sub-treatments, and split variables.

	Spacing / Plant placement	t_1 = 4 m		t_2 = 8 m		t_3 = 12 m		
		V_1	V_2	V_1	V_2	V_1	V_2	Av. Treatment
Date of planting	T1 = 24 Dec 2006	318.6 bc	729.2 ab	515.7 a–c	733.3 ab	350.4 bc	1087 a	622.3 A
	T2 = 28 Jan 2007	450.5 a–c	668 a-c	550.2 a-c	624 a-c	333.4 bc	699.6 a–c	554.3 A
	T3 = 11 Mar 2007	45.4 c	65.5 bc	58.9 bc	106 bc	46.2 c	126.3 bc	74.7 B
	Av. Sub-treatment	t1 = 379.5 A		t2 = 431.3 A		t3 = 486.8 A		
	Av. plant placement	V1 = 296.6 A			V2 = 537.6 B			

c. Reduction of time and cost at the nursery stage.
d. Ease of handling and transporting seedlings from the nursery to the field.

The earlier that forage shrubs are planted at the beginning of the rainy season, the more the plant can benefit from water harvested, which reflects positively on its productivity. However, there will be a higher risk of delay in rainfall and harsh weather conditions affecting the vulnerable young seedlings.

Transplanting after the first good rainfall events reduced the risk of drying out and proved to be beneficial for survival of plants.

Planting young seedlings in early spring is risky, especially if there are no good rainfall events afterwards. Nevertheless, good results are expected if good rainfall events occur in March–April, which is common in the Badia environment.

The transplanting unit can be attached to a furrow opener, making one integral machine that can perform both operations of opening the WH structure and planting the shrubs in one pass. This should dramatically reduce the time and cost of establishment.

Planting in the bottom 1/3 of the ridge showed better plant growth, thus it is recommended to change the common practice of placing the shrubs in the bottom of the catchment furrow and plant them in the lower half of the ridge.

6.2 Introducing a tractor laser-guiding system

6.2.1 Introduction

With the purpose of re-vegetating low rainfall areas in the Jordanian and Syrian Badia, numerous WH systems and techniques have been tried and investigated and positive achievements demonstrated over thousands of hectares. Such techniques have included small-scale water microcatchments opened on the contour lines of sloped areas (contour furrowing). Nevertheless, a major problem with large-scale implementation of WH structures is low capacity of machinery.

By opening continuous and intermittent furrows at a rate of 15–20 ha/d, the Vallerani mechanized system provided a solution for the machinery problem. Given the harsh topographic conditions of the Badia, such capacity is acceptable for large-scale implementation. Nevertheless, the system did not reach its potential capacity due to the slow surveying and marking of contour lines which precede the furrowing. A three-person team can mark contour lines at most at 50 ha/d.

Consequently, it was thought to add an auto-guiding system, which enables the tractor to follow the contour lines 'on-the-go'. Many auto-guiding systems were suggested for this purpose, but most were expensive and/or complicated. The most appropriate one found was the laser guiding system (LGS)(Gammoh and Oweis, 2011).

6.2.2 The use of laser guiding in land leveling

Rice farmers were the first to recognize the importance of effective land leveling to improve yields and conserve water, so they switched from costly and time-consuming traditional leveling methods to the ones involving LGS in cut and fill operations performed by a tractor and a hydraulically controlled grading blade or bucket. This is now commonly used in agricultural applications in Australia, Japan, and the United States. The same concept is being increasingly used in mining and road construction applications.

How it works

The LGS consists of:

- A laser transmitter that transmits a rotating laser beam. The laser transmitter mounted on a tripod allows the laser beam to sweep above the tractor unobstructed with the plane of light above the field.
- A laser receiver mounted on a mast on the grading blade that is hitched to the tractor (Figure 6.3) intercepts the laser beam, detects the position of the laser reference, and sends a signal to a control box.
- An electrical control box which interprets the signal from the receiver, magnifies it, and produces an actuating signal.
- An electro-hydraulic control valve receives the signal from the control box and controls oil flow in order to raise or lower the leveling bucket or blade. Lowering and raising of the blade is the actual leveling action performed by the tractor.

6.2.3 Introducing laser guiding to contour furrowing

Application description

The application is a heavy-load tillage that consists of opening deep (30–60 cm) continuous or discontinuous furrows using the Vallerani or similar plow on the contour lines on slopes of grade 1–7%. If working on one hilly field, passes might be ≤ 300 m in length, but if the situation allows, the tractor might continue its pass and switch to the neighboring hill if it can follow the same contour line. The distance between two successive furrows could be 4, 6, 8, or 12 m. Therefore, the respective falls in elevation between them are:

On a 2% slope: 8, 12, 16, and 24 cm
On a 4% slope: 16, 24, 32, and 48 cm
On a 6% slope: 24, 36, 48, and 72 cm

Scenario of guiding

In contour furrowing, the LGS can detect and measure the difference in elevation between the current tractor position (while traveling) and the reference point in the field and convert this reading to a display on a panel in front of the tractor operator, who can then easily steer the tractor to keep this difference unchanged and maintain the tractor's track on the contour line. In this case, the devices required are a laser transmitter mounted on a tripod, a laser receiver (of specific length) mounted on a mast (either manually or electrically operated), and an electrical control panel with visual and sound display.

The transmitter transmits a laser beam, which is intercepted by the laser receiver mounted on a mast on the tractor (not on the implement), and sends a signal to the control panel. The control panel interprets the signal from the receiver and displays a visual and sound signal. The signal should indicate not only the matching of levels, but also how far (up or down) the levels do not match so the tractor driver can decide whether to steer left or right to maintain travel on the contour. This is true as far as the beam is intercepted by

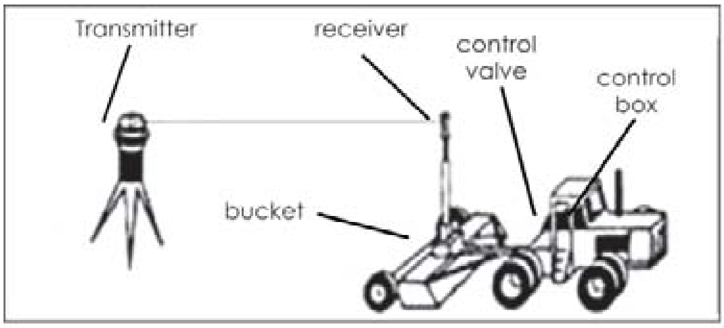


Figure 6.3. Laser guiding system used for land leveling.

the receiver. Therefore, the length of the receiver determines the difference in elevation that the receiver can detect and determines the time that the display can show a reading on the display.

There are five possible guiding situations that a driver might face while driving on a contour line and each has an appropriate response to maintain travel on the contour. A skilled driver should work within the first three possibilities: a–c (Figure 6.4).

When switching to the next downhill (uphill) contour line, if the receiver can still intercept the laser beam the driver can continue plowing without any adjustments. If not, the receiver should be raised (lowered) on its mast until the signal is displayed and travel can then continue.

When it is not possible to raise or lower the receiver due to insufficient length of the mast, the transmitter with its tripod should be relocated downhill (uphill) so the receiver can intercept the laser beam.

Calculations

In order to investigate and negotiate the specifications of laser equipment with the manufacturer, the scenario of guiding in contour furrowing was analyzed and the parameters A, B, and C (Table 6.3) were calculated. These calculations were used also to determine the feasibility, capacity and the appropriateness of the laser guiding system in practical implementation of contour furrowing under conditions that prevail in the Badia.

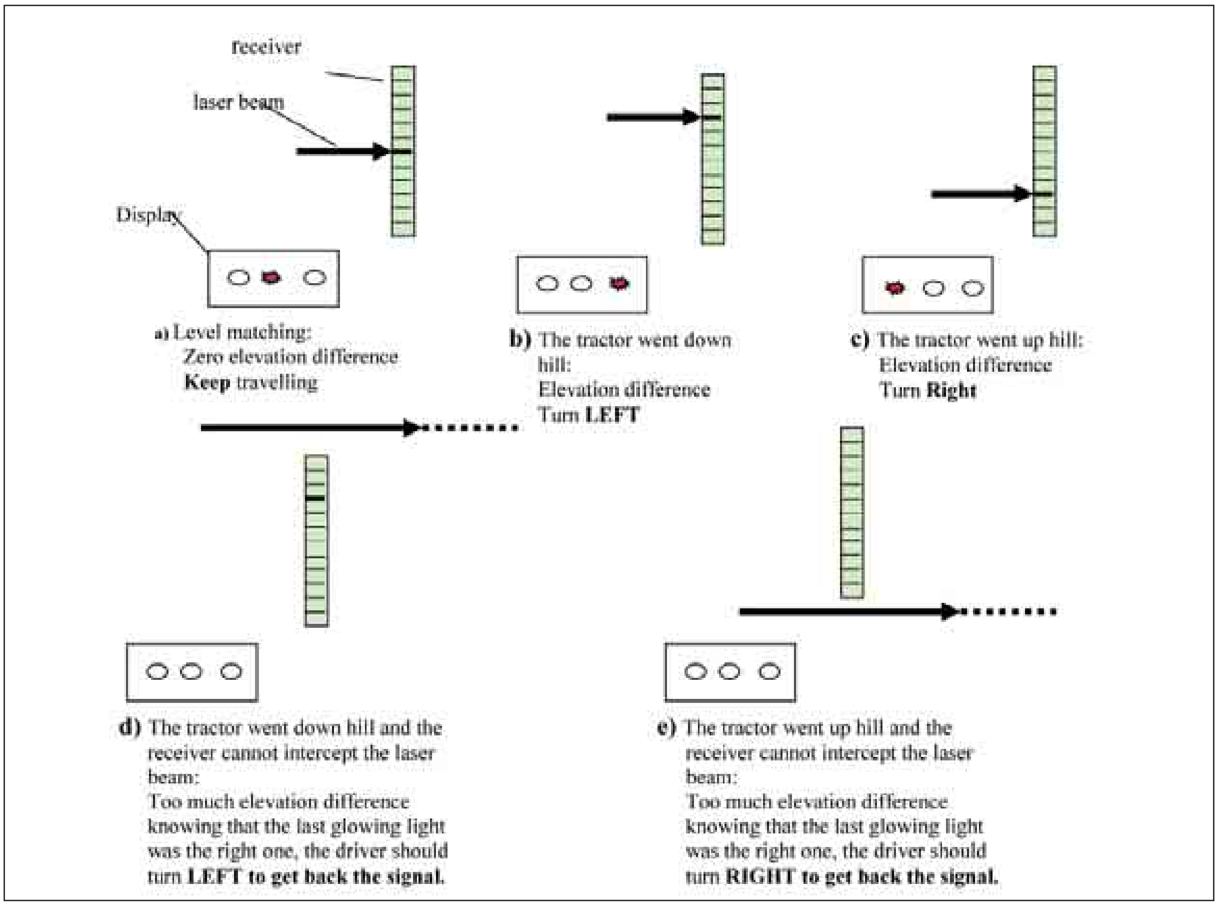


Figure 6.4. Five possible guiding situations met while driving on a contour line.

Table 6.3. Number of furrows that can be made 'on-the-go'.

Furrows spacing	Slope											
	to 2%			to 4%			to 6%			to 8%		
	A	B	C	A	B	C	A	B	C	A	B	C
4 m	8	4	15	16	2	7–8	24	1–2	5	32	1	3–4
6 m	12	2–3	10	24	1–2	5	36	1	3–4	48	1	2–3
8 m	16	1–2	7	32	1	3–4	48	1	2–3	64	1	1–2
12 m	24	1	5	48	1	2–3	72	1	1–2	96	1	1

The fall in elevation when moving from the uphill furrow to the next downhill furrow in cm.

A = percentage slope × furrow spacing

The number of furrows that can be made without any need to readjust the position of the receiver on the mast.

B = L/A (Rounded), where

L - Length of photocells on the receiver L = 31 cm (according to manufacturer specifications)
The number of furrows that can be made without any need to lower the transmitter on the tripod or to relocate it downhill.
C = D / A (Rounded), where Adjustable difference in alleviation between the transmitter and the receiver on the mast according to ordered devices D = 120 cm
The parameters B and C are good indicators of ease and feasibility of performing the furrowing 'on-the-go'. The higher they are the less action is required by the operator while traveling.

Example of capacity calculation

The area that will be covered when working 8-m-spaced furrows on a 4% slope before the position of the transmitter needs to be changed can be calculated as follows:

From Table 6.3, C = 4 furrows can be made without the need to relocate the transmitter.
If four furrows of length 300 m and 8-m spaced and 1-m furrow width, then the area worked without the need to relocate the transmitter will be 300 m × 9 m × 4 = 10 800 m^2 = 1.08 ha

The calculations were based on the specifications and features of the cheapest available laser devices that can be bought and provide acceptable performance of the guiding system. Performance enhancement is certainly possible, but it will be either of additional cost by buying devices of upgraded specifications, or by encouraging the manufacturers to produce devices that suit this particular application.

Nevertheless, with the minimum performance parameters, the laser guiding system proved to be an adequate solution for implementing large-scale applications such as WH contour furrowing.

6.2.4 Disadvantages and suggested enhancements

Unlike land-leveling applications, coverage area should be larger

Suggestion:
Use laser transmitter of higher transmitting range

Frequent re-adjusting of receiver position on the mast, every 1–3 contour furrows, depending on slope

Suggestion:
Use longer receiver
Use electrically adjustable mast, so the driver can relocate the receiver while driving

Frequent relocation of the transmitter, every 3–6 contour furrows

Suggestions:
When the transmitter is on the uphill side, the receiver mast should be selected as tall as possible and the transmitter tripod adjustable as low as possible, and vice versa when the transmitter is on the downhill side.

Notice from the calculation (example above), that in making four furrows the fall in elevation will be: 4 × 32 cm = 128 cm. This is the minimum difference in heights required between the transmitter and receiver, knowing that the adjustable difference in elevation between the transmitter and the receiver on the mast is D = 120 cm (i.e. 8 cm less than the fall in elevation). In this case, the transmitter tripod can be lowered by an additional > 8 cm to plow the fourth furrow 'on-the-go' without needing to change the transmitter position.

When working uphill–downhill, the mast should be mounted at the highest point possible on the tractor, and the transmitter tripod at the lowest point possible.
When working downhill–uphill, the mast should be mounted at the lowest point possible on the tractor, and the transmitter tripod at the highest point possible.
Field work should be performed in long-contour furrows rather than short ones, e.g. by switching from one hill to another adjacent.
Use of a dual-grade transmitter.

Shaking and vibration of equipment while traveling due to undulating soil surface might affect mast rigidity and control box operation

Suggestion:
Heavy duty and shock absorbing mounts should be used

6.2.5 Benefits of LGS

Time and effort saving: In large-scale implementation of WH structures, it is critical to start and finish land preparation before the first rain. This will help in timeliness and improve WH systems management.

Cost reduction: Traditional land surveying costs (surveyors and equipment) is higher than the cost of LGS – especially over many years, and considering that the targeted areas of interventions are of low productivity.

Ease of operation: Traditional surveying needs at least two skilled surveyors; however, the LGS can be operated by one person with minimum training.

High accuracy: Tractor drivers move between marks made by surveyors in straight lines, which affects the accuracy of tracing the contour lines. However, while in LGS the operator is guided to trace the contours continuously. This ensures even elevation inside the catchment and thus even distribution of harvested water along the catchment. In addition, LGS avoids occasional confusion of close adjacent surveyors' marks by the driver and driving toward the wrong mark.

The LGS can be also used as surveying equipment with even farther range of coverage than traditional surveying equipment, and can guide as many surveyors or receivers as necessary.

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