A high yield automatic tree planting machine

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Abstract: The labor shortage, the need to increase the forest density and the great increase in surface for planting trees has led to a reflection in R&D. This article discusses the abilities of a tree planting machine which works automatically. The need to design this type of machine was due to the massive exploitation of forests done by the wood industry and subsistence farming. The device which is hitched up to a tractor can plant in the presence of tree stump and vegetable wreckage. Several hydraulic actuators work in parallel to enable the plantation of one tree per second (a machine with two planting organs). The planting organ has been designed to plant trees without stopping the tractor.

1 INTRODUCTION

The tree planting volume has considerably increased during the last decades due to the massive destruction and massive exploitation of forests. This massive exploitation was mainly caused by the increase in population and by the growing wood needs. The massive destruction was caused by storms.

Tree plantation is realized manually for most of the time. 80% of the trees are planted by hand in France. This type of plantation is difficult, fastidious, slow and the cost of labor is constantly increasing due to labor shortages.

The labour recruitment process had never been efficient. The weaknesses have been attributed to a lack of dedication of the workers resulting in extremely high turnover of manpower. One option to alleviate the labour shortage is increased mechanization. However mechanized plantation in forests is extremely limited due to the maladjustment of the existing planting machines. These issues have led us to a new reflection in R&D.

2 PLANT AND SOIL TYPES

A study of the soils and the plants is primordial to design an efficient machine. Three forestry cooperatives have helped us gathering information about the plant and soil types: "Alliance Forêt Bois", "Forêts et Bois de l'Est" and "COFORET". These three cooperatives have different types of soil and plant trees for various industries. Our quest was to design a machine that satisfies the needs of all these cooperatives.

2.1 The plants

Forest industries plant trees for three main reasons: for biomass, furniture and construction. We can see in the table below, the tree species for each field.

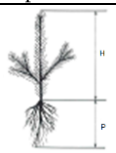
Table 1: Type of plantation

	Short rotation coppice (biomass)	Furniture/ construction
Tree species	Poplar, eucalyptus, willow, black locust	maritime pine, Douglas fir, black locust
Stem diameter	< 7 cm	10cm to 15cm
Density (stem/ha)	6000 to 15000	2000 to 3000
Exploitation age	< 5 years	7 to 10 years

Short rotation coppice (SRC) provides a recognised sources of biomass. This woody solid biomass can be used in applications such as district heating, electric power generating stations, alone or in combination with other fuels.

Trees can be conditioned in three forms (see table 2). The volume occupied by these types of conditioning must be closely analysed to be able to make an optimised machine.

Table 2: Plant conditioning

Exposed roots	Plants in clods	Cutting
 H min: 10 cm H max: 80 cm P max: 20/30 cm	 The volume of the clods is bewteen 100 to 400cm^3	 Length of 20 to 30cm and diaméter of 1 to 3cm
Black locust	maritime pine, eucalyptus	Willow, poplar

2.2 Soil types

The design of the machine depends on the characteristics of the soil. There are three types of soil: clay soil, loamy soil and sandy soil. Soils with large clay content are renowned for their ability to shrink and crack compared to the structure of free draining sands and gravels. Clay soil is sticky and must be removed from the moving parts of the machine.

3 EXISTING TREE PLANTING MACHINES AND INSTRUMENTS

A technology surveillance approach has allowed us to identify the existing machines around the world. Even though several machines have been developed during the 70s, there is actually few forest planting machines that are running. These devices help to plant 20% of the forest in France. We will present below two types of existing machines and one instrument used to plant trees in their different conditionings.

3.1 Bracke planter

The carrying capacity of this planter (figure 1) is 80 plants and thus must be refill about every 32 minutes. The average productivity is 150plants/h.

Figure 1: A Bracke planter mounted on an excavator.

The main advantage of this planter is that it can plant trees on forestland after clear-cutting with the presence of tree stumps. But the planting capacity of 150plants/h is too low for the plantation of SRC according to "Alliance forêts Bois". The carrying capacity is also insufficient. This planter can only plant trees in clods.

3.2 Double disc planting machine

There are several planting machines that use a double disc system to open the furrow where the operator can insert a plant. Two wheels (figure 2) are used to close the furrow. This type of machine can adapt itself to the planting speed of the operator. The maximum speed is about 1800 plants/h (one tree each 2 seconds).

Figure 2: A double disc planting machine hitched up to a tractor.

The main advantage of this machine is its plantation speed. But that type of machine can't plant in forestry condition. It only works on well prepared ground. This planter can plant trees in their three different conditionings.

2.1 Plantation cane (stick)

This plantation cane is widely used by operators to plant on difficult ground conditions. This instrument

weight about 4kg and helps the workers to plant at a relatively high speed compare to the use of a shovel. The plantation speed depends mainly on the ability of the person using it.

Figure 3: Three operators using plantation canes

The main advantage of this instrument is that it avoids the operators to frequently bend over. But the weight of the cane and of the trees makes this type of plantation very fastidious. That is why there are fewer workers who are willing to continue this type of job. Our technology surveillance has allowed us to notice that there is actually any planting machine or instrument that enables to plant trees precisely in forestry condition at a high speed.

4 DESIGN OF THE PLANTING MACHINE

A planting machine has been designed to resolve the issues seen on existing machines. The device has initially been designed to plant wood energy parcels in forestry conditions, but it can be used to develop agroforestry, to regenerate forests destroyed by storms and to plant trees at road edges.

The innovation in this machine is that the plantation is made at constant speed and in the presence of tree stump and vegetable wreckage. An RTK GPS system helps the machine to plant with a precision up to 5cm at a rate of one tree per second (a machine with two planting organs). A patent has been deposited on December 2015.

4.1 Characteristics of the GC-planter

This machine named "GC-planter" has been designed to plant clod plants automatically, but it can plants semi-automatically, trees with exposed roots and cuttings.

Area of use:

- The GC-planter is made of two planting organs.
- The planting organs are separated by a distance of 3m to 4,5m (inter row gap)
- The intra row gap is between 0,5m to 10m

The chaotic environment in forests (tree stump, rock, branches, etc.) has obliged us to put a closer attention to all mechanical parts in contact with this environment. The plantation is made using a beak which penetrates the soil and opens to liberate the plant (see figure. 4).

4.2 Protecting the planter against the topological soil variability

A security measure along the Z axis (figure. 4) has been made to interrupt the planting cycle if the beak meets an obstacle. The beak moves up if it can't penetrate the soil due to a hard objet. It stays at 60cm above the ground for 1 second and the cycle continues after hopefully crossing the obstacle. This system minimizes the contact of the planting organ with the ground, allowing to plant between rocks and tree stumps.

Other security devices have also been designed along the X and the Y axis to protect the plantation organ. These devices use springs that allow the plantation organ to rotate along the Y axis if it meets an obstacle along the X axis and to rotate along the X axis if it meets an obstacle along the Y axis. The planting organ is therefore protected against obstacles such as rocks and tree stump in all directions.

4.3 Plantation organ

Two compacting arms have been designed to compress the soil with a force of about 800N around the plant after plantation (see figure. 4). These arms have also been places on both sides of the beak to remove sticky soil (clay soil). Hydraulic actuators which can work at a pressure of 180 bars are used to make these different movements.

We have got some encouraging plantation results during the first test of this machine. We have however placed overs on the slides to prevent the penetration of dust and soil.

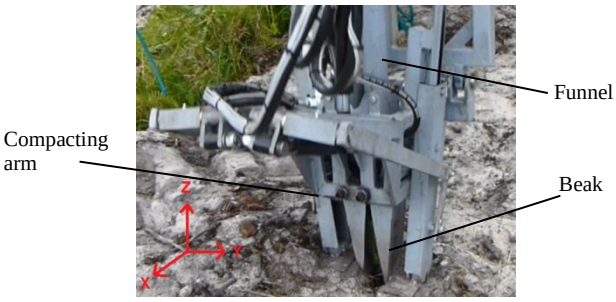


Figure.4. the planting organ

Automatic settings enable the GC-planter to plant vertically on a 25% inclination and a 25% declination ground. This avoids the trees to be bent. Bending trees can't be used for construction. The trees in the figure 5 below were planted perpendicularly to the slopes.


Figure.5. non vertical trees

4.4 RTK GPS

Maintenance tools hitched up to a tractor must be able to travel in straight line between planted trees. Thus, trees must be planted at regular distances in both directions. This planter has the ability to plant in rectangle with a +/- 5cm precision on both sides. The distance between each tree can be 4m on the row and 2m between the rows for example. The GC-planter uses an RTK-GPS to determine the plantation spot.

RTK is a highly precise technique that results in +/- 2 cm pass-to-pass and year-to-year accuracy. RTK GPS requires two specialized GPS receivers and two radios. One GPS receiver is set up as a base station within a 9.6 km radius of the field where the tractor is places so it can send the correction message to the roving receiver. Both receivers collect extra data from the GPS satellites known as L2 Band, which enables this better precision.

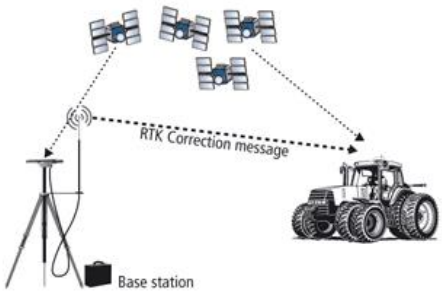


Figure.6. RTK configuration

4.5 Automation

The wood energy field needs a plantation density greater than that of a classic forest. The storage system for one plantation organ consists of a mobile part which has about 1250 plants and a fixed part with 1250 plants. The storage capacity of the whole machine is around 5000 plants during the plantation. An automated system moves the plants from the mobile storage system to the planting organ.

The two planting organs are fixed on both sides of a telescopic beam. The telescopic beam enables the GC-planter to have a width under 3,5m during road transportation. Hydraulic cylinders are used to adjust the distance separating the planting organs. The distance between the plantation lines can be modified from 3m to 4,5m. This distance between them is constant during the plantation. These hydraulic cylinders allow the planting organs to move in parallel and thus to plant in straight line by using the kinematic RTK-GPS system.

The GC-planter is driven hydraulically and each movement can be modified by a programmable logic controller. The control panel which is present in the tractor's cabin allows to start and to stop the plantation, to record the geo-tracking of each plant and to record the characteristics linked to the plantation.

4.6 Kinematics of the GC-planter

The planting organ is made of two deformable parallelograms that are oriented using hydraulic actuators. The parallelogram which is fixed to the frame of the planting machine (figure 7) helps to move the beak according to the Z axis and the other parallelogram allow the beak to move according to the X axis. The figure 7 illustrates the movement of the planting organ during one complete cycle. The planting organ goes back to the 1st position after the 4th position.

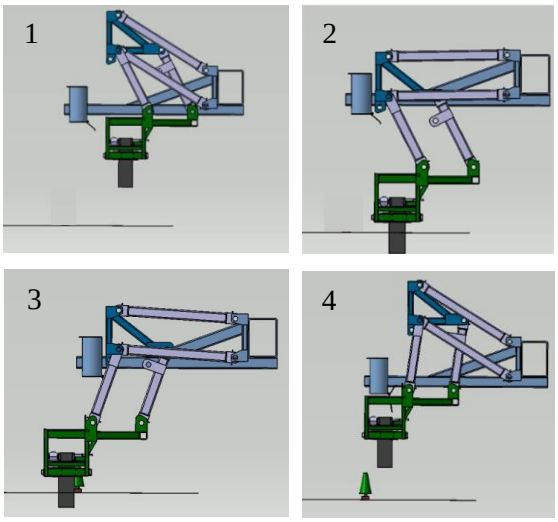


Figure.7. kinematics of the GC-planter

5 RESULTS OF THE TESTS

"Alliance Forêts Bois" is actually testing the GC-planter in real condition. This company is financing the construction of the prototype. The planting organ is being tested and the programs are being adjusted. The machine is actually fixed on the three point hitch of a category three tractor.

We have noticed that during the plantation, the machine needs to be stabilized by adding wheels. Two wheels systems are being added to the GC-planter to increase its stability. The wheels will also help to position the planting organ at a constant height above the ground.

6 CONCLUSIONS

We faced a lot of challenges during the design of this disruptive planting solution. We noticed that the most difficult part was to be able to secure the mechanical parts in this chaotic forestry environment. These security measures guaranties however the efficiency of the planting machine.

Thanks to this machine, we hope to be able to face the reforestation difficulties and the labor shortage.

7 ACKNOWLEDGEMENTS

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