Capstone Design Proposal

Team:	Max Bormes
Class:	ABE 495
Instructor:	Murphy
Sponsor:	Perkins' Good Earth Farm
Topic:	Garlic Production
Date:	January 13, 2012

Writing Lab Technician:	____________________
Instructor:	____________________
Technical Advisor:	____________________
Sponsor:	____________________
Student:	____________________
	____________________
	____________________

Executive Summary

High quality garlic production is often done by hand due to the intricacies of good garlic farming practices and relative cost of appropriate machinery, as employed by the client. Unfortunately, pure manual human farming of garlic is far too taxing on the bodies of the workers involved, and production is limited to a very small scale. A solution must be investigated to retain high quality production, while alleviating the risk of worker stress, fatigue, and injury while also providing a means to scale up production. Fully automated systems do not yield the quality control necessary for the clients high quality needs. Therefore, a human/cart hybrid planter/harvester will be designed to allow for workers to plant and harvest garlic in a comfortable position, while moving along the rows. This will greatly reduce the risk of worker fatigue, stress, and injury while also increasing overall planting/harvesting efficiency. Aside from the initial investment, this is a direct improvement upon the previous system of pure manual labor and handles not only planting, but can accommodate weeding, harvesting, and mulching as well.

Introduction

Perkins' Good Earth Farm is a high quality garlic producer located in DeMotte Indiana. Managing only a quarter acre of land for garlic production, their emphasis is quality above quantity. Perkins' faces two major problems in their current situation:

1.) Their manual human planting/harvesting system has become far too stressful on the bodies of the workers involved.
2.) With increasing market demands, scaling up is necessary but not feasible in their current state: improvements need to be made to allow more land to be planted/harvested in a smaller amount of time.

This proposal will go into detail regarding the various options available to begin scaling up garlic production past manual human labor. It will utilize a full literature review of the various options available to weigh the pros and cons, in order to make an educated recommendation for the client. The final recommendation will also include a list of deliverables that will be provided to the client, a detailed budget breakdown, an overall project plan to assure deadlines will be met, and a management plan for the team working on this project. After this proposal has been approved, detailed design and construction will begin according to the project plan.

Literature Overview

Table of Contents

Table of Figures

*Almost all referenced figures are taken directly from videos of garlic planting, which can be viewed on YouTube. When a figure is referenced, it is highly recommended to watch the video associated with that figure to not only get a better view/perspective but to see different garlic production devices in action. Images are hyperlinked to the videos if using a digital copy of this proposal.

Introduction to Garlic Production

Planting Factors

The production of garlic presents several challenges unique to its species, making manual human production a still viable method:

- *Bulb must be separated into cloves:* Usually done by hand prior to beginning planting regardless of the use of machines or human planters.
- *Seed Depth:* ~Four to six inches.
- *Spacing:* Two to three plants per row, but up to six in some extreme cases, with five to six inches between plants, and eight to twelve inches between rows.
- *Clove Orientation:* Cloves must be planted with the top (pointed end) facing up.
- *Clove stability:* Cloves are not extremely delicate, but like any seed must be handled with care.

Planting/Harvesting Technology

Garlic planting/harvesting can be accomplished through three main methods:

1.) *Manual Human Systems:* All work is done by humans, very little use of machinery. Typically used for small scale production.
2.) *Human/Cart Hybrid Systems:* A cart is pulled behind a tractor that allows planters to sit in a comfortable position while working. Typically used for medium scale production.
3.) *Fully Automated Systems:* The only worker needed is the tractor driver who pulls a fully automated planter or harvester. These systems are expensive and high in error, but can cover massive amounts of land in short amounts of time. Typically used for large scale production.

The following sections will go in-depth into these various Planting/Harvesting Technologies, compare them, and come to a recommended solution.

Planting Technology

Method 1: **Human Planters**

(fig. 1)

Description

Human planting is the process of manually planting garlic cloves without the use of a cart apparatus or any other planting devices. Planters carry around containers of garlic cloves which are then placed individually into either premade holes, or holes made by the planters themselves. Stooping is the main position one is found in, in order to both move and plant efficiently.

This is the method currently being implemented by the client.

Pros

- *Low Fixed Cost:* No machinery to purchase.
- *High Level of Quality Control:* Since a human is there planting every clove, there is always someone checking to make sure quality is being assured i.e. no mechanical grabbing mechanisms are involved; clove handling is done with the highest degree of care and each clove is guaranteed to be planted with the top (pointed end) facing up.
- *High Level of Versatility:* This method could be used to plant many crops other than garlic, and harvesting can be done using the same system.
- *Low Complexity of Labor:* All it takes are workers, some basic training, basic tools, and raw materials.
- *Low Complexity of Design:* It does not require an engineer to design this system.

Cons

- *High Risk of Worker Stress/Fatigue/Injury Rate:* Stooping over for long periods of time while planting is extremely hard on the backs and joints of the planters involved. This is unacceptable to the client at its current level.
- *High Marginal Cost:* To increase production, more workers need to be hired or current workers given more hours and therefore total cost of production goes up proportionally making it difficult to increase profit past a certain threshold.
- *Low Efficiency:* Hand planting takes the longest of all the methods per worker involved. This increases total cost of production, decreasing profit.

*These will be the primary factors evaluated throughout the report where applicable.

Conclusion

Manual human hand planting is a very feasible solution for a budding garlic farm but falls short in the long run. The toll on the human body is far too great. Since this is the **method currently employed** by the client, and the worker stress level is far too high, this method cannot be continued and new options need to be investigated. Implementing even a basic machine to assist in planting can alleviate body stress almost entirely while also increasing efficiency. Continuing use of this system is not recommended.

Method 2: **Human/Cart Hybrid Planters**

(fig. 2)

Description

This is the natural next step in scaling up production after manual hand planting. Many different variations of garlic planter carts have been developed, but the idea is simple and universal: make planting easier and faster. There are two main types of carts, each with individual variations.

Tractor Powered:
In this method human planters ride in a cart pulled behind a tractor. This cart usually seats *two* planters (fig. 2), but some setups can allow for as many as *four* (fig. 3), with each planter responsible for one row of crops. The tractor slowly pulls the cart and allows the planters to assume a comfortable position to plant while still moving along the row.
Self-Powered:
In this method the cart itself provides the main source of power for its movement. This can be done simply through *human power* or the use of a *gas*, *hydraulic*, or *electric* motor.

The following pages will discuss the various planter cart design options in-depth.

Cart Options

Propulsion

- ***Human:*** No figure provided, but similar to figure (3) without the motor; in this method, the human planter(s) provide the propulsion needed to move the cart along the rows. This is usually done through simple pushing, but it is possible a sitting bicycle-pedal powered apparatus could be devised.

  Pros

  - *Low Fixed Cost:* Since no motor or complex drive train needs to be purchased, it is the cheapest of all the propulsion systems. Although a more complex method than simple pushing could add to the cost, it would likely still be substantially cheaper than any of the motorized propulsion methods.
  - *High Quality Control:* No potentially harmful chemicals are used in this method.
  - *Low Complexity of Design:* The simplest of all the carts to design for, and the easiest to understand how to use.
  - *Moderate Efficiency:* Yields a ~40% increase in planting/harvesting time compared to manual human methods. It also only requires one laborer per cart as a separate driver is not needed, but it is very difficult to make human powered carts that support more than one worker per cart.
  - *Low Quantity of Labor Required:* This system can be achieved by a single worker and therefore is optimal for the client.
  - *High Reliability:* The simplicity of the cart system means it can likely be maintained without the need for trained personnel.

  Cons

  - *Moderate Risk of Worker Stress/Fatigue/Injury:* This is still a much better option than no-cart human planting, but only really eases comfortability rather than physical exertion. Although increased comfortability may entail less overall exertion and mechanical advantage can be used to increase energy-use efficiency.
  - *Low Torque:* A fully loaded cart may simply be too difficult to push with human power. Also, if excessive human power is required to push the cart although possible, than this method loses its efficiency benefits. Impossible to accomplish the tasks of row making and/or filling/smoothing automatically due to increased resistance.
  - *Moderate Complexity of Labor:* Workers will likely have to create a divot and fill/smooth the hole as a row making device and/or filler/smoother would cause too much resistance for human power to overcome efficiently. Workers also have to push the cart entirely themselves adding to labor complexity.

- ***Tractor***: As seen in figure (2); in this method the cart is pulled by a tractor.

  Pros

  - *(Potentially) Low Fixed Cost:* As long as a tractor is already owned that fits the rows and has the proper torque, then no extra systems need to be purchased for propulsion.
  - *Low Risk of Worker Stress/Fatigue/Injury:* Since the worker no longer has to provide propulsion for the cart, substantially less exertion is required and the worker can potentially attain a more comfortable position.
  - *Low Complexity of Design:* A simple hitch is all that needs to be designed to allow for this cart to be connected to the tractor and propelled.
  - *Low Complexity of Labor:* Workers likely will not have to create divots and/or smooth/fill after planting, simplifying the process.
  - *Moderate Efficiency:* Workers can work longer and faster due to removing propulsion and potentially row making and filling/smoothing, while in a more comfortable position. Although this method requires a separate driver, requiring at least two planter/harvesters minimum to justify driver cost.
  - *High Torque:* Tractors can provide the power to achieve row making and filling/smoothing, while also potentially carrying more than one to two planters.
  - *High Reliability:* Since the cart itself is very simple, it has a very small risk of failure.

  Cons

  - *(Potentially) High Fixed Cost:* If a tractor is not owned or it does not fit the rows or have the proper torque, then this is a very expensive option.
  - *Moderate Quality Control:* Although purpose-built, tractors still pose a risk of leaking fluids and damaging crops.
  - *High Quantity of Labor Required:* This system can in no-way be achieved by one person, which is not optimal for the client.

- ***Onboard Motor***: As seen in figure (3); in this method, either gas, hydraulic, or electric power contained onboard the cart is used to propel the cart along the rows.

  Pros

  - *Low Risk of Worker Stress/Fatigue/Injury:* Since the worker no longer has to provide propulsion for the cart, substantially less exertion is required and the worker can potentially attain a more comfortable position.
  - *Low Complexity of Labor:* A simple throttle is all that is needed to move the cart, and divot making can possibly be achieved automatically.
  - *High Efficiency:* Allows the planter/harvester to take all their focus/energy away from propulsion and entirely into their task, while allowing workers to work longer shifts, improving efficiency further. No separate driver is needed which also increases efficiency.

- *Moderate Torque:* Especially during harvesting, carts can get very heavy and can be very difficult for a human to push. This will alleviate the propulsion needed by the human, and should be able to accomplish row making and possible filling/smoothing.
- *Low Quantity of Labor Required:* This system can be achieved by a single worker and therefore is optimal for the client.

Cons

- *High Fixed Cost:* A separate propulsion system will be the most expensive option outside of purchasing a tractor.
- *Moderate Quality Control:* All the options pose a risk of leaking harmful chemicals on to crops, as even electric systems require batteries that contain harmful chemicals. This can be minimized significantly.
- *Moderate Reliability:* These systems can break and trained maintenance will likely be required to fix them.
- *High Complexity of Design:* Adding a drive system increases design complexity significantly over human or tractor powered systems.

Conclusion

The client requires a system that can be used by a single individual, therefore a *tractor pulled* cart is *not recommended.* Both the human-powered and engine-powered carts are very viable options. A fully loaded cart moving along actively growing cover crops is going to be extremely difficult to push, so it is recommended that some other sort of propulsion beyond human *pushing* is required, although, this does not rule human *power* out completely. With the demand for extremely high quality control the client has, the risk of leakages from the various engine-powered systems is unsatisfactory. The initial upfront cost and reliability/maintenance of these systems is not optimal either. Therefore, it is recommended the client investigate a method that utilizes highly geared bicycle pedals to slowly move the cart along the rows. Pedaling would be easy, but require many rotations to move the cart small distances. This allows for high torque, without the need for high worker strength or exertion. Since planting is a slow process anyways, this would work perfectly.

This idea may be too risky, as it has not seen major production. If that is the case, the small risk of leakage, high initial cost, and maintenance factors do not outweigh the low torque of human pushing and an *engine-powered system is recommended*. The various types of engine configurations will be discussed in detail.

(fig. 3)

(fig. 4)

Motor Types (Onboard Engine-propelled Carts only)

- ***Gas:*** As seen in figure (3); uses gasoline as fuel to power the motor.

  Pros
  - *Low Fixed Cost:* Gas engines are cheap and available.
  - *Low Complexity of Design:* Gas engines are easy and common to design systems for.
  - *Moderate Reliability:* Gasoline systems are relatively robust, easily replaceable, and many people have general knowledge of the systems to help with maintenance, reducing the need for trained maintenance.
  - *Moderate Torque:* Although not as strong as hydraulic systems, these should still be able to accomplish the tasks of row making along with filling/smoothing.
  - *Moderate weight:* Since gasoline needs to be stored, this is still a moderately heavy system.

  Cons
  - *Moderate Variable Cost:* Gas prices consistently increase, and these will need to be constantly filled.
  - *Moderate Quality Control:* Gasoline leakage would be very detrimental to crop growth. Also fumes would not be optimal for workers and crops either.
  - *High Noise:* Gas engines are very noisy due to explosive expansion/compression.
- ***Hydraulic:*** As seen in figure (4); uses fluid pressure to power the hydraulic motor.

  Pros
  - *Low Variable Cost:* A battery can be used to power the compressor, so charging is all that is required to keep these powered.
  - *High Reliability:* Hydraulic systems are very robust, but will likely require trained maintenance if they do break.
  - *High Torque:* Hydraulic systems have very high torque and could accomplish the tasks of row making along with filling/smoothing.

  Cons
  - *High Fixed Cost:* Hydraulic systems are quite expensive.
  - *Moderate Quality Control:* Hydraulic fluid leakage would be very detrimental to crop growth. Although these system are designed to have nearly zero leakage, and with good seals this can be achieved.
  - *High Complexity of Design:* Hydraulic systems are relatively more complex to design than other systems.
  - *High Weight:* Hydraulic systems are very heavy and bulky.

- ***Electric:*** As seen in the video attached with figure (3); uses electricity from a battery to power an electric motor.

  Pros

  - *Moderate Fixed Cost:* An electric motor with the torque required for this will likely be more expensive than a gas engine, but cheaper than a hydraulic system.
  - *Low Variable Cost:* A battery is used for power, so charging is all that is required to keep these carts running.
  - *High Quality Control:* The only risk of damage to the crops would be from battery acid leakage. This can be easily contained and risk reduced highly.
  - *Low Complexity of Design:* Electric motors are relatively easy and common to design systems for.
  - *Moderate Weight:* Since a battery is needed, this system is still moderately heavy.

  Cons

  - *Low Reliability:* Electric systems are generally less robust than other methods.
  - *Moderate Torque:* Although it cannot achieve the torque levels like that of a hydraulic motor, there are high-torque electric motors that should work for a planter cart, but it will require more gearing.

Conclusion

All three motors are quite viable solutions. A *hydraulic system* is too high-weight, expensive, and complex for the client's needs therefore that system is *not recommended.* Due to its high quality control, low noise and variable cost relative to the gas motor, a **high-torque *electric motor* is the recommended solution** for a motor-powered cart.

<u>Seat Level (Tractor-Pulled Carts only)</u>

- ***Ground-Level Seats****:* As seen in figure (2), these seats hover or are dragged at ground level directly above the soil.

  Pros
  - *High Quality Control*: Since planters have direct access to the soil, the only thing out of their control is rate of movement (which is very slow), giving this method almost identical quality control as human planting. This means all cloves are being handled with the highest degree of care possible and being planted in the most accurate orientation possible.
  - *High Versatility*: This type of seating configuration can also allow for harvesting, weeding, and mulching.
  - *Low Complexity of Labor*: A separate harvesting device does not need to be used.

  Cons
  - *Moderate Efficiency:* It is not feasible to make this configuration allow for more than four plants per row (with each planter handling two rows), since it is not feasible to add more than two ground-level seats, although usually, this still more than acceptable in most situations.
- ***Raised Seats****:* As seen in figure (5), these seats are raised significantly above ground level. Planters use a chute of some sort to direct the clove from the raised position to the soil.

  Pros
  - *High Efficiency:* Can accommodate up to four planters and possibly even more in a custom device, allowing for the maximum amount of rows to be planted in one pass.

  Cons
  - *Moderate Quality Control:* While a human is still there overseeing the planting the distance between the planter and the soil opens up room for error. Plant spacing must be controlled solely by the planter since he/she is not close enough to aim for premade divots; i.e. plant spacing must be estimated. Also clove orientation may not always be proper due to orientation changing during the short free-fall through the tube/chute to the soil.
  - *Low Versatility:* The distance from the soil makes this an impossible solution for human/cart hybrid harvesting or weeding, although mulching may still be possible.

Conclusion

The added potential efficiency of the raised seat carts does not outweigh the greater level of versatility and quality control one gets from the ground-level seat carts. The fact that the **ground-level carts** can be used to plant, weed, harvest, and mulch considerably increases its value, making it the **recommended choice**.

<u>Row-making and Filling/Smoothing Methods:</u>

Planters need a small divot in the soil to plant the clove within, followed by soil to fill in the divot after being planted. This is accomplished using a row making device, followed by a filler/smoother. This process can be done separately or be integrated into the cart itself.

- ***Integrated****:* As seen in fig. (2), the spiked wheel row maker is integrated into the cart ahead of the human planters.

  Pros

  - *Low Complexity of Labor:* Overall planting process is simplified, i.e. no switching out of different carts, less passes. Also, integrating a simple row maker into any cart system is not an overly complicated task.
  - *High Efficiency:* Less passes need to be made with the tractor, decreasing overall time needed to plant.
  - *High Quality Control:* Rows are guaranteed to work and be aligned with the planting cart, as it is directly integrated.

  Cons

  - *Low Complexity of Design:* Although a con, since this system is still more complex than a separate row making system, overall complexity is still *low*.

- ***Separate****:* As seen in fig. (6), this separate apparatus is attached to a tractor, where it is pulled behind before planting begins to create the rows and divots for which to plant in.

  Pros

  - *(Potentially) Low Fixed Cost***:** Since this device is relatively common, it is likely already owned and therefore would cost nothing. Regardless, it is still a relatively cheap to device to purchase.
  - *High Versatility:* This device can be used to begin the planting process for many other types of crops.
  - *Extremely Low Complexity of Design:* An engineer is not needed to utilize this system.

  Cons

  - *Low Efficiency:* An entire separate set of passes need to be made with this device prior to planting, and another set of passes after that if the cart does not integrate a filler/smoother.

Conclusion

The only reason to separate the row maker/smoother from the cart is if these device(s) are already owned. Even if that is the case, it would not be difficult to integrate it into the cart. The integration of these devices simplifies the whole planting process to more-or-less one pass, decreasing time and effort significantly at the cost of very little added design complexity and cost. Therefore, the **integrated system is recommended.**

(fig. 5)

(fig. 6)

<u>Row Making Devices</u>

- ***Spiked Wheel***: As seen in figure (2), this a metal wheel with metal spikes welded around the circumference. The wheel rotates ahead of the human planters as the tractor moves, creating divots about 1 inch deep for planters to plant the cloves in. These spikes are spaced appropriately (~4 inches apart) to create proper spacing between each plant. The number of rows of spikes used is determined by the number of planters being utilized in the planter device; i.e. one row of crops per planter per row of spikes.

  Pros
  - *High Quality Control*: Creates divots at the exact right spacing.
  - *Low Torque*: Does not incur significant resistance to cart's forward motion.

  Cons

  N/A
- ***Double Moldboard Plow***: Similar to the setup in figure (8). This device creates a seam in the soil for seeds to be placed in.

  Pros
  - *Low complexity:* Works well for non-human planting systems as there is not as small of a target for the clove to be placed in.

  Cons
  - *Low Quality Control:* This method requires planters to estimate spacing. This adds human error that could lower production yield. Also the clove is not as well encapsulated meaning it can change its orientation more easily after being placed into the soil.
  - *High Torque:* Incurs very high resistance to carts forward motion.
- ***Chisel Plow***: As seen in figure (7). Shares the same general properties as the double moldboard, although can work on rougher terrain.

Conclusion

Although moldboard and chisel plow row makers work, the added quality control from the spiked wheel makes it the obvious choice. The other plows do not really add anything besides human error. Also, since the client specified using actively growing cover crops, with no till, this method is the only solution that can handle those conditions while not completely destroying the cover crops. Therefore the **spiked wheel** row maker is the **recommended** solution.

(fig 7)

(fig 8)

<u>Filling/Smoothing Devices</u>

- ***Single Roller:*** One single horizontal roller comes through after everything to compact the soil. Works well in moderate and intensively tilled soil.

- ***Dual Angled Wheels:*** As seen in figure (9). Two angled wheels direct soil towards the divot and also compact. Works well in almost all levels of soil tillage.

- ***Reverse Moldboard Plow:*** Opposite of a moldboard plow, these plows funnel the soil back together, filling a gap made by a moldboard plow exceedingly well. Works well in intensively tilled soil.

- ***Chicken Wire (soil scraper):*** Something as simple as chicken wire can be dragged behind to help smooth soil over the planted cloves. Works well in intensively tilled soil.

Conclusion:

There is very little difference between the various methods of filling/smoothing. As long as one method is chosen, it will likely accomplish its goal as well as all the others. For the client's specific needs, the dual angled wheels will likely accomplish the goal most effectively due to the limited amount of loose soil. Therefore **dual angled wheels** are the **recommended** solution.

<u>Extra Option(s)</u>

- ***Direct Chemical Sprayers:*** As seen in figure (2) (the round drums are filled with fertilizer), chemical sprayers can be added to allow for direct injection of chemicals into the soil during planting.

  Pros

  - *High Quality Control:* Chemical added directly after planting can aid plant growth increase yield, and garlic quality.

  Cons

  - *High Fixed Cost:* Spraying devices can get expensive, and the cart itself will need to be built stronger to support the weight of the chemical reservoirs.
  - *High Design Complexity:* Adding a sprayer not only adds an entire new element to the cart, but requires the entire cart be built to accommodate large chemical reservoirs.
- ***Awning:*** Provides shade from the sun.

  Pros

  - *Low Risk of Worker Fatigue/Stress/Injury:* This prevents heat stroke and exhaustion.
  - *Moderate Efficiency Increase:* Workers can work longer in the sun.

  Cons

  - *Low Fixed Cost:* There is a cost to this, but it is small.

Conclusion

Chemical spraying likely needs to be done several times after planting regardless, and therefore adding this to the planting process does not increase efficiency but simply adds a small element of quality control. This small amount of quality does not outweigh the increased cost to the cart and therefore is **not recommended** for the client’s needs.

Adding an *awning* not only lowers worker fatigue/stress/injury but also increases efficiency and is therefore worth the small upfront cost of adding one to the cart, and therefore is a **recommended** option.

Overall Pros of Human/Cart Hybrid Tractor-Towed Planting

- *Low Risk of Worker Stress/Fatigue/Injury*: The human/cart hybrid planter alleviates the toll on the human body almost entirely by placing the planter in a comfortable position.
- *Moderate Marginal Cost*: To produce one more unit of output, it costs less input relative to manual planting as only one laborer is needed who also can work much faster relative to other methods.
- *Moderate Efficiency:* The entire planting process is streamlined and simplified as opposed to manual hand planting. Planting will take less time overall with the same amount of workers.
- *High Level of Quality Control:* With humans still in control of the actual planting process, the highest level of quality control is possible.
- *High Versatility:* Not only can this cart be used for planting garlic but for weeding, harvesting, mulching, and even planting other types of crops.
- *Moderate Complexity of Labor:* This method adds a bit of complexity over complete manual human planting, but after a little training it will become just as simple, if not easier.
- *Moderate Complexity of Design:* While not as complex to design as a fully automated system, there are definitely design challenges that need to be tackled.

Overall Cons

- *Moderate Fixed Cost*: Building a cart apparatus will not be as cheap initially as hand-planting, but is still significantly less expensive than a fully automated system.

Overall Conclusion

Combining the various conclusions from each subsection allows for an overall conclusion to be made for human/cart hybrid systems.

There are three valid solutions:
Tractor-Towed: A tractor-towed cart system using ground-level seating, a spiked wheel row maker and double-angled wheel filler/smoothers.
Onboard Motor: An electric motor powered cart utilizing a spiked wheel row maker, and double-angled wheel filler/smoothers.
Human Power: A highly geared bicycle pedal powered cart, accomplishing row making and filling/smoothing by hand.

Of these three valid solutions, the *human powered* solution is the **recommended** solution for its relative low upfront cost and complexity, its high level of quality control, and its ability to allow for a single person to utilize it completely. This is the overall **recommended** solution for the project and should see an at least ~40% increase in efficiency over hand-planting as well.

Method 3: **Fully Automated Machine Planters**

(fig. 9)

Description

Fully automated planters attempt to remove as much human labor as possible from the planting process. This greatly increases efficiency as planting can be done faster, and therefore lowers marginal cost, as much less labor is needed to produce the same amount of output. These systems work especially well for large-scale garlic production where quantity is being valued higher than quality.

Automated systems use the same row forming and filling/smoothing mechanisms as human/cart hybrids. Where fully automated systems differ, though, is that they rely on a device to remove a clove from the hopper and plant it into the soil, rather than a human. There is really only one main approach to this process, with slight variations to improve accuracy.

In figure (10) three fully automated garlic planters can be seen. The majority of this device is a rectangle hopper filled with garlic cloves. Within each hopper is a wheel that rotates through it. On the inside (our left) of each wheel is a hook designed to grab a clove as it moves through the hopper. This wheel is tied directly to the drive wheels so as the tractor moves; it spins, picks up cloves, and then drops them into the soil.

More complex devices, like that seen in figure (9), use pneumatic suction to draw individual bulbs out of the hopper before loading them on a similar rotating wheel. This reduces the amount of missed cloves, as the hooks are not 100% effective. This increases the amount of cloves planted and therefore increases crop yield, at the cost of increased initial investment.

Pros

- *Lowest Worker Stress/Fatigue/Injury Risk:* The only worker is the driver, who is in a comfortable sitting position.
- *Low Marginal Cost*: To produce one more unit of output, it costs very little input since only one laborer is needed who also can work much faster relative to other methods.
- *High Efficiency*: Can plant extremely fast, covering many times the amount of area human planters or human/cart hybrid planting can accomplish in the same amount of time.

Cons

- *High Fixed Cost:* This is most complex device, requiring the most intricate parts and high quality engineering and is therefore the most expensive to purchase up front.
- *Low Quality Control:* Especially in systems that do not utilize pneumatic suction to draw out individual bulbs, many bulbs are missed and therefore spacing can become irregular. Also it is difficult to ensure proper bulb orientation upon plating. Bulbs are not handled with the same level of care (although again, pneumatic systems help) as a human handler and can risk damage prior to planting.
- *Low Versatility:* This device cannot be used for weeding, harvesting, or mulching, and will be difficult to adapt to other crops if necessary.
- *Moderate Complexity of Labor:* Workers will need to know how to operate this device, and maintain it when one its many moving parts eventually breaks.
- *High Complexity of Design:* The design process for this type of device would be very long and intensive due to its relative complexity.

Conclusion

Automated garlic planters are great for large scale production, but not for the client. Quality control is far too low. The amount of missed and damaged cloves would not compensate for the increased efficiency for non-large scale farms. Also, it does not solve the problem of human taxation during weeding, harvesting, and mulching. Therefore this method is **not recommended** for the client.

(fig. 10)

Harvesting Technology

Method 1: **Human Harvesters**

Description

In this method human harvesters walk around and collect each bulb from the soil by hand. Little to no machinery is used to assist in the process.

This is the current method employed by the client.

Pros

- *Low Fixed Cost:* No machinery to purchase.
- *High Level of Quality Control:* Since a human is there picking every bulb, even bulbs whose stems break can still get harvested and handled with the highest level of care.
- *High Level of Versatility:* This method could be used to harvest many crops other than garlic.
- *Low Complexity of Labor:* All it takes are workers, some basic training, and basic tools.
- *Low Complexity of Design:* It does not require an engineer to design this system.

Cons

- *High Risk of Worker Stress/Fatigue/Injury Rate:* Stooping over for long periods of time while harvesting is just as bad as planting. This is unacceptable to the client at its current level.
- *High Marginal Cost:* To increase production, more workers need to be hired or current workers given more hours and therefore total cost of production goes up proportionally making it difficult to increase profit past a certain threshold.
- *Low Efficiency:* Hand harvesting takes the longest of all the methods per worker involved. This increases total cost of production, decreasing profit.

Conclusion

Human manual hand harvesting is a very feasible solution for a budding garlic farm but falls short in the long run. The toll on the human body is far too great. Since this is the method **currently employed** by the client, and the worker stress level is far too high, this method cannot be continued and new options need to be investigated. Implementing even a basic machine to assist in harvesting can alleviate body stress almost entirely while also increasing efficiency. It is **not recommended** to continue using this method.

Method 2: **Human/Cart Hybrid Harvester**

Description

This device is essentially the same as the Human/Cart Hybrid Planter only without any row makers, fillers/smoothers, planters, etc. It is simply a cart with seats at ground level, that allow for human harvesters to be towed behind a tractor in a comfortable sitting position while they harvest. It would look similar to the cart seen in figure (2) with the spiked wheels removed.

Pros

- *Low Risk of Worker Stress/Fatigue/Injury***:** This alleviates the toll on the human body almost entirely by placing the human harvester in a comfortable sitting position.
- *Moderate Marginal Cost*: Since harvesting will be more efficient, one worker can harvest more crops and therefore total cost of production decreases, increasing profit.
- *Moderate Efficiency:* The entire planting process is streamlined and simplified as opposed to manual hand harvesting. Planting will take less time overall with the same amount of labor.
- *High Level of Quality Control:* With the use of ground-level seating quality control is on par with manual planting.
- *High Versatility:* Not only used for harvesting, but weeding, planting, and mulching.
- *Moderate Complexity of Labor:* Adds a bit of complexity over complete manual human harvesting, but after a little training it will become just as simple, if not easier.
- *Moderate Complexity of Design:* While not as complex to design as a fully automated system, there are definitely design challenges that need to be tackled. If a hybrid planter cart is available, it is just a matter of making certain pieces removable.
- *Low to Moderate Fixed Cost*: With a human/cart hybrid planter already built, there would be no other devices needed to purchase, otherwise it is just a very simple, cheap cart.

Cons

N/A

Conclusion

Since a human/cart hybrid planter is the recommended system for the client, the human/cart hybrid harvesting system is a natural second step. There is no need to buy new equipment and it is a direct improvement upon manual harvesting. When harvesting time comes, the planter cart can simply be stripped of everything but its seats and used to harvest. The same reservoirs used to hold cloves for planting will hold the harvested garlic. Automated harvesting would require an entirely separate cart, of a very high degree of complexity which would be a separate project entirely. Therefore this is the **recommended** harvesting system for the client.

Method 3: **Fully Automated Harvester**

Description

As seen in figures (11) and (12), fully automated garlic harvesters exist, but like their planter counterparts, are designed for large-scale garlic production where quantity is valued highly relative to quality. These devices funnel the garlic stem into a device which lifts the bulb by the stem, out of the ground and into a hopper.

Pros

- *Lowest Worker Stress/Fatigue/Injury Risk:* The only worker is the driver, who is in a comfortable sitting position.
- *Low Marginal Cost*: To produce one more unit of output, it costs very little input since only one laborer is needed who also can work much faster relative to other methods.
- *High Efficiency:* Can harvest extremely fast, covering many times the amount of area human harvesters or human/cart hybrid harvesting can accomplish in the same amount of time.

Cons

- *High Fixed Cost:* This is most complex device, requiring the most intricate parts and high quality engineering and is therefore the most expensive to purchase up front. It is also a completely different device than the planter and therefore would be a separate project.
- *Low Quality Control:* Especially in systems that do not utilize pneumatic suction to draw out individual bulbs, many bulbs are missed and therefore spacing can become irregular. Also it is difficult to ensure proper bulb orientation upon plating. Bulbs are not handled with the same level of care (although again, pneumatic systems help) as a human handler and can risk damage prior to planting.
- *Low Versatility:* This device cannot be used for weeding, planting, or mulching and will be difficult to adapt to other crops that are not very similar to garlic.
- *Moderate Complexity of Labor:* Workers will need to learn how to operate this device.
- *High Complexity of Design:* The design process for this type of device would be very long and intensive due to its relative complexity, and would be separate from the planter.

Conclusion

Automated garlic harvesters are great for large scale production, but not for the client. Quality control is far too low. The amount of missed and damaged cloves would not compensate for the increased efficiency for non-large scale farms. Also, it does not solve the problem of human taxation during weeding and harvesting. Therefore this method is **not recommended**.

(fig. 11)

(fig. 12)

Mulching

Description

Mulching is the process of spreading organic materials over growing crops. Mulching helps regulate soil temperature, adds a layer of protection, adds moisture to the soil, and helps prevent weed growth.

Conclusion

While mulching is a necessary process for garlic production, it is completely separate from the planter/harvester cart design. The degree of difference in applying mulch versus planting/harvesting garlic is not conducive to combining into a single speficic device. Separate mulching devices exist specific to the type of mulch being used. It would be too difficult and overall ineffective to add this to the planting/harvesting device.

Although, depending of the type of mulch the human/cart hybrid planter/harvester will likely be able to accommodate mulching as well when stripped of its planting accessories as done when harvesting/weeding, making it an even more advantageous and versatile option. Therefore, it is *recommended to either purchase a separate mulching device or use the human/cart hybrid machine to mulch as well.*

Final Recommendation

After extensive weighting of the pros and cons of the various options for the client throughout the literature review, the conclusions drawn make it easy to identify the most optimal solution for the client’s needs. Please refer to the individual pros, cons, and conclusions for a more detailed analysis on the recommended items.

Manual production is the current method being employed and falls short in terms of worker stress/fatigue/injury risk and production efficiency. This method is **not recommended** to be continued to meet the client’s needs.

Since this is not large scale production, quality control is of such high importance and the client has specified that garlic must be hand planted, *fully automated systems* are **not recommended**.

This leave only one real option, although it an exceptional match for the client’s needs. The **recommended** solution is the *Human/Cart Hybrid Garlic Planter/Harvester*. This system allows for the high level of quality control needed by the client, alleviates problems with worker stress/fatigue/injury, and will increase production efficiency allowing for production to be scaled up in the future.

Design recommendations for human/cart planter/harvester *options*:

- *Human Powered:* This system will still provide a notable (~40%) increase in planting/harvesting/mulching efficiency while completely solving the problem of worker stress/injury/excess fatigue. It is the cheapest and simplest cart propulsion system. This makes it the simplest to design, implement, and troubleshoot. Since it still fulfills the design goals, which already make it an optimal solution. This system also provides the highest level of quality control, putting humans at ground level in charge of the actual planting and harvesting and does not have the risk of harmful chemical spill like gas, hydraulic, and even electric powered systems. While a tractor pulled system would be just as effective, it requires a separate driver and a tractor itself, which is undesirable for the client who would like the system to be usable by a single individual, and not incur the reduced quality control from the tractor. A highly geared bicycle-pedal powered system should be investigated as opposed to simple pushing, to provide more torque, with less input force.
- *Separate Row Makers and Filler/Smoothers:* Not enough torque to accomplish these tasks, but these can be done with a separate device, or by the planters themselves.

Deliverables

1.) A formal literature review of garlic production technology.
2.) Detailed designs and specifications of the Human/Cart Hybrid Garlic Planter/Harvester.
3.) A working prototype Human/Cart Hybrid Garlic Planter/Harvester.

Project Plan

Task	Deadline
Submit Project Proposal	Jan. 13, 5:00 PM
Make necessary changes and obtain final approval	Jan. 20, 5:00 PM
Obtain any measurements, on-site data, loading requirements, etc	Jan. 27
Finalize Design/Cost Analysis	Jan. 31
Order Parts	Feb. 1
Begin Construction	Upon arrival of parts
Working Prototype Finished	Feb. 23, 3:00 PM
Final Report and Poster	Mar. 2, 5:00 PM

Budget

A budget of five thousand dollars has been proposed by the client, but not confirmed. A detailed cost analysis will be made upon proposal approval, and final design of the cart.

Management Plan

Since there is only a single team member, Max Bormes will be in charge of any design, building, or other tasks needed to complete this project.

Alternate Solutions

See the literature review for various alternate solutions discussed and analyzed in-depth. These include devices such as raised seat human/cart hybrid planters, fully automated planters, tractor pulled carts, and on-board motor-powered carts.

Bibliography

Perkins, Dan. *Perkins Garlic*. Perkins' Good Earth Farm, 2011. Web. 13 Jan. 2012. <http://www.perkinsgoodearthfarm.com>.

"Pendragon Fabrication Contact Information." *Welding, Metal Fabrication, Design and I nstallation By Pendragon Fabrication*. Web. 20 Jan. 2012. <http://www.pendragonfabrication.com/pages/drangen.html>.

"A Specialized Harvest Cart for Greens."

"Growing Garlic, Harvesting Garlic, Planting Garlic, Garlic Scapes." *Organic Seed Garlic – Boundary Garlic, BC, Canada*. Boundary Garlic, 2011. Web. 13 Jan. 2012. <http://www.garlicfarm.ca/growing-garlic.htm>.

"Piper Planting Garlic.AVI - YouTube." *YouTube - Broadcast Yourself.* Web. 13 Jan. 2012. <http://www.youtube.com/watch?v=lDpdrgv48NI>.

"Planting Garlic with Water Wheel Transplanter - YouTube." *YouTube - Broadcast Yourself.* Web. 13 Jan. 2012. <http://www.youtube.com/watch?v=dgERKjTieEw>.

"Lay- Down Work Cart - YouTube." *YouTube - Broadcast Yourself.* Web. 20 Jan. 2012. <http://www.youtube.com/watch?v=OGn_FYRGIdE>.

"Planting Garlic - YouTube." *YouTube - Broadcast Yourself.* Web. 13 Jan. 2012. <http://www.youtube.com/watch?v=1SjnJil6TaQ>.

"Garlic Row Marker - YouTube." *YouTube - Broadcast Yourself.* Web. 13 Jan. 2012. <http://www.youtube.com/watch?v=lmCExdV7KJQ>.

"Schuster Farm Garlic Picker Planting Machine - YouTube." *YouTube - Broadcast Yourself.* Web. 13 Jan. 2012. <http://www.youtube.com/watch?v=M3IFK2EWJME>.

"ERME: 3 Row Pneumatical Planter.wmv - YouTube." *YouTube - Broadcast Yourself.* Web. 13 Jan. 2012. <http://www.youtube.com/watch?v=sikWhEgCBNE>.

"ERME: Mechanical Garlic Planter PLMS3.wmv - YouTube." *YouTube - Broadcast Yourself.* Web. 13 Jan. 2012. <http://www.youtube.com/watch?v=0vave0bg-RY>.

"ERME: 4 Row Garlic Harvester Binder.wmv - YouTube." *YouTube - Broadcast Yourself.* Web. 13 Jan. 2012. <http://www.youtube.com/watch?v=tSJnOseBuDc>.

"ERME: 1-row Garlic Harvester-binder.wmv - YouTube." *YouTube - Broadcast Yourself.* Web. 13 Jan. 2012. <http://www.youtube.com/watch?v=FUw9FHnSevk>.