Floating fields tree and plant production

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Abstract. The challenge of lowering tree production costs to address depletion in global forest cover and timber supply is addressed. Research was driven by the desire to develop a system of tree production so inexpensive that trees could be produced by government and private nurseries at inconsequential cost for free or low cost distribution for mass tree planting to help world-wide tree supply catch up to demand. The research goal was to lower to two pennies the cost of tree production during the critical 90 day period after a cutting or bare root seedling is planted in a nursery to the time the plant grows into a field ready seedling. The research followed rigorous objectives to achieve vast reduction in infrastructure, maintenance, chemicals, irrigation technology and labour to create high-volume, high-density outdoor and indoor tree production. Costs during the ‘critical ninety days’ were brought down to near zero in some trials. Key to this achievement was proving the hypothesis that sub-irrigated plant production is possible by placing tree cuttings and bare root seedlings into buoyant planting blocks floated in a wide variety of outdoor water bodies and indoor water pans. The system also proved until for production of a wide range of forbs, vascular plants, grasses and select vegetables. The extreme water saving characteristic of the floating fields system was a subsequent discovery not hypothesized. Successful floating field production of trees, grasses, vegetables and a wide range of aquatic and dryland plants suggest that sub-irrigation in general and floating fields in particular represents a major breakthrough in agriculture. Larger implications of this discovery are expected to show dramatic lessening of the cost of plant production worldwide with desired consequences for the planet including but not limited to improved forest cover, greater industrial timber supply, and improved food security.

1. Introduction

Rapid deforestation particularly in the southern hemisphere and consequent eroding landscapes, desertification, and watershed depletion resulting in drying lakes and rivers, and greatly altered rainfall threatening agriculture is negatively impacting the quality of mammalian and human life in those regions. Human and animal life on earth and most energy for industry is dependent on oxygen supply to burn fuels. Meaningful life on earth cannot exist without trees to produce oxygen, consume and convert carbon dioxide, stabilize climate and contribute to earth shade and rainfall.

Trees are so essential to life and industry that availability of trees can no longer be left to normal market forces using current tree production processes and technologies which require inordinate amounts of infrastructure, land space, water, technology and skilled labor. Due to the extreme numbers of trees required to catch up to current rates of deforestation, it is unrealistic to assume government and donor funds can meet tree needs based upon current tree production costs. An alternate system of lower cost tree production is required to ensure tree availability worldwide at negligible cost.
1.1 Synergy with Jua Kali movement principals
The many research objectives to reduce costs follows not only the researcher’s lifetime commitment to zero waste but also has synergy with the Kenyan Jua Kali movement. Jua Kali in the Swahili language means ‘outdoor sunshine’ referring to the starting of businesses without access to buildings, capital, equipment, raw materials nor infrastructure. It was a successful movement developed by and for communities without economic means [1].

The research also found synergy with the self-help principals of the Savrodayo Shramadaya movement of Southeast Asia that influenced the researcher’s early thinking i.e.: that one can improve one’s lot and the quality of the world around us by mobilizing existing resources in one’s immediate environment [2].

1.2 Building on prior experience and non-documented innovations by the researcher
The researcher observed in his international agro-forestry work that trees flourish in some of the most degraded landscapes and sometimes in tiny cracks of otherwise solid rock masses, on near sheer cliff faces, in nutrient poor soils, and sometimes flourishing in 100% waste compounds not recognized by biologists as plant soil at all. The researcher also observed that trees the world over but particularly in arid and semi-arid climates obtain the vast majority of their water requirements through natural sub-irrigation i.e.: through absorption of water from at and below the root level up into the plant instead of absorbing water as it percolates downward through the soil profile as during rainfall events or during top irrigation.

The researcher began developing a hypothesis that trees, made up roughly of 50% water and 50% carbon obtained the vast majority of its carbon during tree’s conversion of atmospheric carbon dioxide while releasing oxygen back to the atmosphere. It was further hypothesized that trees may be using the earth mostly as a place to anchor and obtain water and that tree requirements for minerals and micro nutrients were far more minimal than previously believed. The sub-irrigation hypothesis was built on two additional researcher experiences:

- Tree bare root seeding beds germinated and grew more optimally when beds were saturated with water once per day through flood irrigation rather than overhead irrigation. Leaf fungus was far less due to the non-use of top irrigation which creates unnatural levels of humidity.
- Bagged container root trees grew more optimally to field ready seedling using simple technology-free earthen or plastic lined sub-irrigation pans rather than top irrigation systems.

The official hypothesis for the current research is that tree seedlings will thrive under sub-irrigation when floated on water surfaces so long as the correct buoyancy of the planting container can be created. That is, it was hypothesized that trees and other plants could be grown by floating on water surfaces so long as the buoyancy of the container holding the plants was such that sufficient amount of the plant roots could be kept out of the water such that the plants could self-regulate its water requirements.

Sub-irrigation of plants is not a new phenomenon. Various forms of plant sub-irrigation are outlined by Bartok [3] including capillary mat systems, trough system with spaghetti tubes, ebb and flow benches, and flood floors with slotted PCV pipe to supply and quickly evacuate water and nutrients. Conventional sub-irrigation systems however involve specialized technology, structures and processes that are complex and expensive compared to the floating fields system that the current research tests. Trials were carried out at two HELP International tree farms at Weyburn, SK. Canada i.e.: ten acre Queen Street City Farm and HELP’s 160 acre Tree Production, Research and Training Center.

2. Methodology
The researcher intentionally placed the following constraints on research to search for a two penny tree production system:

a) Researcher used existing landforms to test hypothesis that propagation of trees through sub-irrigation on water surfaces is possible. Natural sloughs adjacent to a river were utilized as nursery sub-irrigation water pans so that water could be pumped the short distance overland from the river to fill the sloughs; two dugouts with several feet of water depth served for floating field
nursery trails so that pumps and irrigation equipment could be eliminated entirely in nursery operations. Flat land surfaces that would not require landscaping were covered with a plastic film with raised edges to create extremely low cost portable sub-irrigation nurseries.

b) Modification to existing landforms was minimized to fit the purpose for sub-irrigation nurseries: two sloughs were squared off at the edges with a front end loader to create a dimensional nursery and to create abrupt 12 to 18 inch rises on the shorelines so that floating plant blocks would not beach during wind events. This eliminated the requirement for excavating a water pan because the bowl-shaped slough was a natural pan.

c) Uniformity was created for large scale trials: the most ambitious trial nursery which sub-irrigated 600,000 trees involved the excavation of seven side by side shallow canals over two days at HELP International tree farm at Weyburn, Canada averaging 100 feet long x 25 feet wide x 1.5 feet deep. Drive lanes were left between the canals to test ease of tree access.

d) ‘Bring industry to the energy source rather than the energy source to the industry’: Floating fields tree nurseries were constructed in natural sloughs near the river where water was free except for short distance pumping cost. In another case 600,000 trees were floated directly in the open water body of two dugouts in hopes of eliminating 100% of infrastructure and irrigation equipment requirements.

e) Reduce technology and chemical use: No sprinkler irrigation technology was employed to operate seven versions of outdoor and an indoor sub-irrigation trial nursery. No water purification, nutrient feeding nor PH balancing technology was employed. The trials would test whether trees could propagate and grow without these processes and technologies.

f) Reduce human involvement: Sub-irrigation nurseries were hoped to greatly reduce human labour during the ninety days after plant material was placed for sub-irrigation in buoyant planting blocks up to the time of harvesting.

g) Reduce buildings: The research trials test if greenhouses are truly required for proliferating container root trees from cuttings and whether temporary shade structures are adequate for initial seed germination and for starting cuttings during hot weather i.e.: during July or August in Weyburn, SK, Canada when five or more days typically have temperatures in excess of 30 degrees Celsius. All trees successfully started from conventionally conditioned cuttings during the months of Trials would determine whether May and June were optimal planting months using sub-irrigation floating fields in Weyburn, Saskatchewan when average high daytime temperatures are 18 to 24 degrees.

h) Reduce processes: Compared to conventional indoor greenhouse system of producing container root tree seedlings, the outdoor floating nursery trials would test the efficacy of eliminating typical greenhouse equipment for overhead irrigation, water purification, nutrient feeding, PH balancing, humidity control, and fungus control.

i) Reduce chemicals: No preventive chemicals for pest control nor fungus disease would be applied. It would be observed whether outdoor low humidity and wind conditions could prevent fungal disease.

j) Reduce land space: Trials will test the efficacy of using up to 100% of water surfaces in sub-irrigation.

k) Reduce Water Requirement: Observe water use in hopes of optimizing ways to reduce water consumption during sub-irrigation nursery trials.

l) Reduce Soil Requirement: Test use of styroblocks of four principal plant cell sizes of 60 ml, 105 ml, 170 ml and 340 ml to test whether trees grown in cells with smaller soil volumes could produce trees of equal growth rate, size and hardiness as trees grown in larger volumes of soil.

m) Reduce Skill Requirements: Seek out simplified maintenance systems where plant survival is not dependent upon advanced decision making, quick responsiveness, and advanced problem solving.

n) Reduce business and financial risk of plant nursery operators by seeking out ways of reducing the cost of the initial capital investment. It was hypothesized that using existing water bodies and low cost construction sub-irrigation nurseries would achieve this goal.
2.1 Principal material
Five types of greenhouse styroblocks conventionally employed to hold soil medium and plants for top irrigation in indoor nurseries were tested for the new purpose of plant sub-irrigation. All tree proliferation experiments in which trees and other plants were planted from seed, cuttings, transplanted as container root seedlings from other nurseries or using post germination bare roots utilized nursery soil filled polystyrene planting blocks called styroblocks of 329 square inch (2.28 ft²) area and six inch depth and used all sizes including 44 planting cells of 340 ml; 77 cells of 170 ml; 112 cells of 110 ml; and 195 cells of 60 ml. The ratio of styroblock sizes used in the trial nurseries averaged close to 100 trees per square foot.

These would be used to determine if the buoyancy of styroblocks used in conventional greenhouses when soil and plant filled were sufficient as to allow plants to optimally self-regulate their water needs through sub-irrigation without water logging or drowning when floating on water surfaces. 2.75 inch high polystyrene planting block of similar surface area with 450 cells of 16 ml was also tested. The cells were filled with three variation of soil mix to determine which mix was more conducive to root and stem growth: 1st mixture tested was: 1/3 compost soil, 1/3 fiber (peat moss), and 1/3 inert material (polystyrene beads). 2nd mixture tested was ¼, ½, 1/4. The control tested was: 100% humus soil.

2.2 Test to determine which cutting sizes would be viable for sub-irrigation
A 6 to 36 inch long cuttings of the following tree varieties were tested to determine hybrid poplars including varieties: walker, okanese, assiniboine, hill, tristis, northwest and the following willow varieties: silverleaf, laurel leaf, cherisima, acute, pussy willow. All trials would use cuttings to tested growth and development without the use of any fertilizer.

2.3 Trials to employ a variety of water containments
Trials will be carried out by floating newly planted tree cuttings into eight distinct water holding containments including: constructed troughs of varying depths from 6 to 30 inches, portable single block basin nurseries of four inch and 16 inch depth, portable frame with plastic membrane, natural and modified sloughs into which river water is pumped, water filled dugouts, specially built shallow canals, flat ground surrounded by specially constructed clay berms into which water can be pumped and finally indoor sub-irrigation with portable frame with plastic membrane.

2.4 Trials to test which tree and plant varieties can proliferate in sub-irrigated conditions
All shelterbelt tree varieties available through the Canadian federal government’s agro-forestry center and the Saskatchewan government’s Sask Power Shand Greenhouse will be tested in their ability as tree varieties to proliferate through sub-irrigation. Select tropical tree varieties will also be tested along with select vegetable, grass and forbs to determine their capacity to establish and grow to field ready seedlings in floating nurseries. A number of tree seeds from tropical regions would be tested to determine the likelihood that sub-irrigation could be successfully utilized in southern hemisphere countries.

2.5 trials to test the field viability of tree seedlings produced using sub-irrigation
Trees produced by outdoor sub-irrigation and without any hardening up protocols will be field planted to determine their viability and drought resistance.

2.6 Tests to determine appropriate soils for optimal plant performance in floating nursery
Trials compared efficacy of nursery soils with 1/3 humus, 1/3 fiber (peat moss), 1/3 inert material (polystyrene beads) against ¼ portion humus, ½ fiber content, ¼ polystyrene beads and against a control of 100% humus soil. All soils were tested with tree cuttings in sub-irrigated conditions.

3. Results and discussion
Trees that successfully proliferated from cuttings to field ready seedlings when planted in all sizes of styroblocks tested and in all eight variations of outdoor floating nursery for any ninety day period
between May 1st to August 31 included: black poplar (populous balsamifera), the following hybrid poplar varieties: walker, okanese, assiniboine, hill, tristis, and northwest, willow (salix) tree varieties: silverleaf, pussy, shrub, laurel leaf, beaked, white willow, golden willow, sandbar willow, plus red ozier dogwood (cornus stolonifera). Assiniboine poplar was the only variety of the above trees that suffered temporary clorosis by the fall. However subsequent field planting the next spring showed that this condition did not appear again and showed no residual effect on rate of tree establishment.

a) Inferior Size Container Root Seedlings Transplanted and Grown Out In Floating Field

Inferior size container root plants produced in a conventional greenhouse were transplanted into conventional six inch high greenhouse styroblocks with 112 ml, 170 ml and 340 ml planting cells and set into outdoor floating nurseries. The container roots were placed into the next size larger than their original container size and additional soil was added. They successfully grew out to field ready size within the 90 days test period. They included: green ash (fraxinus pensylvanica), pin cherry (prunus pensylvanica), siberian crab apple (malus baccata), siberian larch, sea buckthorn (hippophae), trembling aspen (populous tremuloides), cottonwood poplar (populous deltoids), red ozier dogwood, velosa lilac.

The following inferior size seedlings which were both container root and bare root seedlings from conventional nurseries successfully grew out to field ready size in six inch high styroblocks outdoor sub-irrigation but performed better in water shallows in water depths of two inches or less or in styroblocks of modified construction such that buoyance ensured one inch or less of the styroblocks submerged below the water surface: blue spruce (picea pungens), white spruce (picea glauca) and chokecherry (prunus virginiana).

The following tree varieties at any size were anathetic to floating on water surfaces and only performed adequately when sub-irrigated on humid ground surfaces with 1mm to 5 mm of water depth: Scot’s Pine (pinussylvestris); Cariganna (cariganna arborescens).

b) Proliferating Tree, Vegetable, Grass, Forb and Vascular Plants from Seed

The following tree varieties were planted by seed into 2.75 inch high 450 cell styroblocs in indoor sub-irrigated indoor nurseries and produced viable seedlings for later transplanting to 112 cell, 105ml six inch high styroblocks for proliferation in outdoor nurseries: Velosa Lilac, Red Ozier Dogwood, White Spruce.

The following tropical tree varieties were germinated in seeding beds in 0.375ft2 micro portable table top greenhouses, then transferred into 2.28 ft2 styroblocks with 112 six inch deep 105 ml planting cells for indoor sub-irrigation in an attic office in portable 2.8 ft2 water pans for sub-irrigation for sixty days after which the planting blocks were placed for another 120 days in an outdoor dugout for sub-irrigation in water depth exceeding five feet till all varieties reached field ready seedling size. The varieties included: Eucalyptus Saligna, Eucalyptus Grandis, Mexican Pine (Pinus ayacahuite), African Cypress (Cupressaceae Widdringtonia), Jacaranda Mimosifolia, Grevilia Rubusta, and Cararina Equisetifolia.

In numerous successful trials Roma and Beefsteak varieties of tomatoes were variably direct seeded and transplanted from germination beds into industry standard styroblocks of 110 ml and 170 ml cells with standard nursery soil mixes and in comparative trials transplanted as few day old germinated seedlings into similar styroblocks and sub-irrigated outdoors to produce hardy six to nine inch tall seedlings that survived field planting with no hardening up protocols required. Initial trial to germinate and grow Broccoli, Cauliflower, Onion, Cabbage, Lemon Grass in floating field also produced viable seedlings.

These were never field planted so field survival and growth rate results were not available. In all three cases of proliferating plants from seed, the buoyant styroblocks were either tied or weighted down in the water pans for the first two weeks after seeding so that water level was within 1.5 inches from the styroblock surface to provide sufficient moisture in the top soil lens for seed germination and initial seedling development. After that time the plant filled styroblocks were sub-irrigated in portable water pans with water depths of 0.5 to 4 inch depths. Trials showed that temporary top irrigation during germination and first two weeks of seedling growth
created conditions for the plants to be able to sub-irrigate in floating fields in the same styroblock they germinated in.

Serendipitous discovery during the course of tree production trials demonstrated the natural proliferation of multitudinous varieties of grasses, forbs and vascular plants in the floating fields system when soil filled plant cells were left vacant of intentional plant culture. Some of the plants that were identified as natural proliferating included: wheat grass (agropyron subsecundum), slough grass (beckmannia syzigachne), foxtail (alopecurus), alfalfa (medicago sativa), Gumweed (grindelia Squarrosa, cattail (typha latifolia), western dock (rumex occidentalis), common plantain (plantago major), cattail (typha) plus many other plants not professionally identified.

Creeping red fescue (festuca ruba) grass was planted in a purposeful experiment at various periods during month of May by seed at a rate of 100 lb per acre of outdoor nursery in soil filled floating styroblocs with 110 ml and 170 ml cells. Tested at the end of the growing season in September of the same year demonstrated 100 % of the cells planted had established vigorous top growth and intensive solid six inch long root plugs.

c) Test Results Determining Tree Cutting Lengths Most Viable for Sub-Irrigation

6 to 36 inch long cuttings of the following tree varieties were tested to determine which hybrid poplars including varieties: walker, okanese, assiniboine, hill, tristis, northwest and which following willow varieties: silverleaf, laurel leaf, cherisima, acute, pussy willow would perform best in outdoor floating fields.

All lengths of cuttings produced viable field ready seedlings within 90 days or less. There was a direct relationship between length of cutting and swiftness of the root to develop into a field ready cohesive root/soil plug. The longer the cutting the faster the root development. The 36 inch cuttings developed to be a field ready saplings the quickest in 8 to 10 weeks. The smallest six inch cuttings typically required 11 to 13 weeks to achieve the same root development result.

d) Test Results for Optimal Soil Mixtures to Employ in Floating Fields

The ¼ humus, ½ peat moss, ¼ polystyrene beads produced the best root development of tree seedlings in floating fields. 1/3, 1/3, 1/3 mix performed adequately but not as superior as the former. Using 100% humus as an experiment control, poplars for example had healthy top grown in ninety days but not any root development i.e.: the cutting remained as a stick in the soil without development of a single root hair. It was observed that the cutting in the floating state could absorb nutrients required from the humus soil without the requirement of a root.

e) Trials to Determine Viability of Water Containments as Sub-irrigation Nurseries

The seven floating nursery designs were set up as trials. The smallest portable nursery held one styroblock of 112 trees. The largest trial nurseries in dugout, slough, and canal nurseries held 600,000 trees. The seven nurseries grew trees of equal health and rapidness of development within the ninety day window from cutting to field ready seedling. The style, shape, or depth of outdoor nursery were not observed as factors in tree proliferation rates or health of trees. In one instance it was noted that the willows in styroblocks that catch on a sandbar rooted out of the bottom of their plantings blocks and into the slough bottom soils.

The difference in floating field nursery design was more defined by the cost of the nursery and the conveniences it provided to the operator. Some of the principal advantages of each are noted below:

| Wooden Trough with Plastic Film Liner | Trial Version, 1,750 ft² | Capacity: 70,000 trees | Construction Cost: $8,662 or $4.95/sq. ft. | Advantages: Tree varieties easy to control i.e.: one tree variety per 100 ft. long trough | Disadvantage: Highest Nursery Cost of Sub-irrigation Models |
| Portable Frame with Plastic Film Liner | Trial Version: 100 sq. ft | Capacity: 3,000 trees | Construction Cost: $78.82 or $0.78/sq. ft. Time to build: 30 minutes. | Advantages: Best do-it-yourself nursery for small scale operator Can upscale using same model |
Can construct on any flat piece of land; Easy to move and dismantle.

**Portable One Block Nursery in 16 inch deep Basin**  Trial Version: 2.75 sq. ft.
Capacity: 198 trees  Cost: $7.00 $2.54/sq. ft.
Advantages: Ideal for Research
  Floating field movable to office or quickly changed to any location.
  Surprising low cost to purchase commercially (storage container)

**Natural Slough Nursery**  Trial Version: 15,000 ft. sq.  Realized Capacity: 600,000 trees
Cost to construct: $1,870 $0.13/sq. ft.
Advantages: Almost no construction cost;
  Small landscaping only to straighten and deepen edges
  Easy to control inventory with floating wood planks (construction cost)
  Smallest environmental footprint; Uses existing landform

**Shallow Canal with Drive Lanes**  Trial Version: 18,200 sq. ft.
Realized Capacity: 600,000 trees cost to construct: $2,510 $0.14/sq. ft.
Advantages: Low construction cost
  Ease of Access due to drive lanes beside systematic rows of shallow canals

**Field Arena with Clay Berm Perimeter**  Trial Version: 10,500 ft. sq.
Realized Capacity: 450,000  Cost to construct: $2,600 $0.25/sq.ft.
Advantages: Can build on any flat piece of land or pavement adjacent to water supply
  Easy Do-it-yourself construction.
Extremely low initial investment.

**Indoor Sub-irrigation Nursery**  Trial Version: 135 sq. ft.  Realized Capacity: 8,500 trees
Cost to construct: Building (uses existing building space)
Cost to Construct Indoor Portable Nursery Frame and Plastic Liner: $105.30 $0.78/sq.ft.
Advantages: can use existing greenhouse, home or office with storefront windows and can create winter time nursery.
Disadvantage: requires protocols and extra time to harden up.

f) **Hardening Up Research**
Unlike the indoor sub-irrigation nursery trial, trees produced in all versions of the outdoor floating nursery did not require hardening up protocols. All trees produced in floating fields survived field establishment and grew at rates typical of container root trees produced in conventional nurseries. The researcher carried out forty eight contract forestry installation contracts using trees produced in floating fields system.

**Testing Growth Rate Without the Aid of Fertilizer**
Several dozen trials were carried out without the aid of fertilizer. All trees started from conditioned cuttings grew to adequate size for field ready seedlings within 90 days from the cuttings being floated with medium in styro-blocks. Trees started from seed were not adequate size for field planting during a single growing season there for fertilizer may well be required to stimulate seedlings started from seed in the floating field nursery system.

**Incidence of Fungal Pathogens in Indoor and Outdoor Sub-irrigation Nurseries**
There were zero incidence of fungal pathogens in three trials carried out with indoor sub-irrigation nurseries. It is believed that the forced air and radiator heating systems in these winter nurseries kept humidity of indoor air very low which helped to prevent such pathogens.
The relative humidity on a typical afternoon at the height of the growing season in August in Weyburn, SK., Canada in the outdoors when the floating fields research was carried out was noted to average 45%. In all trials of the open water outdoor floating fields, at no time did disease develop in trees, grasses, forbs or vegetables though they were grown in densities from 22 to 100 plants per square foot. All such trial nurseries in the open air and unshaded.

The humidity in conventional greenhouses is artificially high relative to typical outdoor environment unless expensive ventilation systems are utilized [4]. This unnatural humidity level relative to the outdoors, adds greatly to the incidence of fungal pathogens in conventional nurseries and suggests why fungal pathogens were not present in any of the floating field trials nor in the indoor sub-irrigation trial. It was clearly observed that the more latent process of sub-irrigation releases far less humidity into the air and onto plant leaves compared to top irrigation methods.

i) Water Consumption Rates of Indoor Floating Field Nursery

Poplar and Willow trees in the indoor sub-irrigated trial nursery utilized an average of 2.95 ml/tree/day or 246 ml per tree seedling over 83.5 days to bring a tree seedling to field ready status. This equaled 147.5 ml/sq. ft./day of nursery space. This surprisingly low water consumption was not hypothesized. This represents a remarkable 93.75% less water consumption than the 1,892 ml/sq. ft./day of irrigation water recommended for contemporary top irrigation greenhouses [5].

j) Water Consumption of Outdoor Floating Field Nursery

Water consumption was measured during the hottest month of August for a 600,000 tree floating field trial in a dugout reservoir at the height of the growing cycle. Water consumption was measured by water surface area x water level change on five measuring sticks implanted in the dugout shallows. Water consumption was 975 ml/sq. ft./day or 19.5 ml/tree/day. This represents 41% of conventional greenhouse water requirements of 2,360 ml/sq. ft. [7]. The sub-irrigation water consumption rate of plants might have been even less as water loss due to percolation and surface evaporation were not measurable and therefore not accounted for and assumed to be zero. The dugout surface was more than 95 percent covered by plant filled styroblocks so surface evaporation (as separate from evapo-transpiration) was estimated at zero. Another exciting discovery was that water use by the floating field of tree seedlings of 0.544 cm per day of water depth in August, 2017 which represented 100% of water loss from the dugout reservoir, was less than the 0.76 cm of water depth that would have been lost to evaporation alone from typical open water surfaces during a similar month of the year for which data is available [6]. This provides exciting opportunities for floating fields to contribute to water conservation in arid and semi-arid climates. Imagine that the presence of 2,400,000 tree seedlings that would fit on an acre water body will actually create a net gain in water than if no trees were present.

It should be noted that a good portion of water in conventional greenhouses is not actually utilized by the plants but lost to run off. This is in part due to the need to over water deciduous trees to compensate for their broad leaves deflection of overhead sprinkler water from entering the root cavity. In addition some irrigation equipment requires water volumes to operate properly that are in excess of plant requirements [7].

k) Cost Comparison in Producing Trees in Floating Fields Vs Conventional Greenhouses

Costing for potential greenhouse operators might be best shown in terms of initial long term investment and then operating costs per crop.

Initial investment for nursery construction, truck and trailers, plus multi-year life span planting blocks for floating nurseries averages CAN$51,000 for a 600,000 tree capacity nursery. A 100% of nursery administration, operating, and production costs per tree in an upscale sub-irrigation nursery is: 9 cents (of a CAN$) per field ready seedling or $54,000 to produce 600,000 field ready tree seedlings. This compares to 18.26 cents per tree for large scale private tree seedling producers [8]. Both values are based upon Canadian labor rates. Labor made up 44
percent of the cost of tree production in the sub-irrigation research trials and 36.5% of the cost of tree production in private tree seedling producers [8]. This suggests that the trees could be produced at even far less cost in parts of the world where labor is less expensive.

Note that equipment needs typical of conventional greenhouse operations were unnecessary in floating field nurseries including equipment for ventilation, humidity control, planting tables, irrigation sprinkler systems, tanks, apparatus and chemical for water purification, fertilizer injection, and PH balancing. In additional the significant costs of conventional greenhouse heating fuel and electricity for lighting are needs that don’t factor into outdoor floating field nurseries. In consequence the cost of tree production in outdoor sub-irrigation nurseries are half that of the capital intensive large scale private nurseries.

Initial investment for land, infrastructure and equipment for floating field nurseries is only 6% that of conventional nursery start-up costs. This make sub-irrigation nurseries very attractive due to the low financial risk associated with the initial investment.

4. Conclusion
The floating fields patented discovery changes in a fundamental way, the means and cost for nursery tree and plant production. Upscale tree nurseries, once seen as the sole domain of government and large entrepreneurs are now accessible to anyone who has a passion to plant trees. Governments on small budgets for environmental programming can now afford to contemplate national free tree programs. NGOs with good logistics and a medium size budget can propagate a million trees per year instead of the labour intensive, high maintenance conventional river side nurseries of the southern hemisphere. Fruit, nut and timber farms can now produce their own seedlings at inconsequential cost. Universities can, at small cost and effort, propagate new plant varieties to provide to the private sector and family farms.

The extreme water saving characteristic of the floating field nursery system holds great promise for tree and other plant production in arid and semi-arid regions of the world where water is scarce. Current ongoing research trials are working toward protocols for thousands of additional plant varieties to be propagated on water surfaces. The researcher believes that multitudes of masters and PhD theses will be written on the hundreds of derivative applications related to this fundamental discovery.

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