Initial study for an urban agriculture installation, modeled on the "Vertical Farm" typology, surrounded by horizontal not extensive agricultural lands

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Abstract.

Tillage is an urban district plantation located inside the city for growing high-quality fruits and vegetables through the use of modern technology (hydroponics, aeroponic, aquaponic, using LED or infrared lamps). Tillage is not a traditional agricultural plantation placed on the outskirts of the city or in the countryside: in TillAge®, the process of cultivation takes place according to the model of the so-called "vertical farm", ie. takes place according to the model of the so-called "vertical farm", ie. using/building structures traditionally used for residential, commercial or business scopes. Depending on the case uses, TillAge® modules (TillA-Module®) can be placed on the roofs of buildings, such as shopping centers or supermarkets. A TillAge® plantation can be realized in ad hoc "buildings" (plant-scrapers), or through the recovery of abandoned buildings TillAge® is the concrete and responsible solution to a dangerously growing trend: the inability, in the short term, to supply of food and water the entire world population.

The actual scenario.

A study of the United States Census Bureau, affirms that by 2050, 80% of the worl population will live in the cities or urban landscapes. If we draw a hypothetical line (conservative) of the population's growth, by 2050 the world population will increase by about 3bn people (9ML in total). In addition to the impact that this may have on pollution and therefore on the climate change, the availability of food resources, including water - so to feed the planet - will become primary in the life of every inhabitant of the planet. If, therefore, the current cultivation practice will remain the same, there will be an increased need for new land to be used as cultivation just to ensure the survival of the world's population: we are talking about 1bn hectares of new farmland. To make a concrete image, we are talking about the entire size of Brazil, added a further 20%. However, today more than 80% of the land is already in use for agriculture, while the remaining 15% is no more available due too extesive usage; 87% of water is used for agricultural purposes, while 850ml of people just today suffer from malnutrition. The current scenario shows a condition that will soon become unsustainable for the planet and that may cause:

- a drastic decrease in agricultural production, almost homogeneously on a global level;
- greater vulnerability to climate change and diseases.

The solution.

As the current crops are totally fossil fuel dependent, this provides a strong risk for the world's population and their livelihood as fossil fuel will no longer be available in 30years. We need a new way of farming, producing high quality food, safer and with a positive impact on the enviroment.

TillAge approach is innovative and keep in strong consideration the threats rising from the dependance on fossil fuel of present agriculture system.

TillAge bases on 6 strong key-points:

1. **high yield, improved quality of food, but at a lower cost:** producing the food locally and selling it directly to the residents of a district, TillAge cuts the cost of transportation and packaging. Combining production and selling in the same place, customers can enjoy fresh and high quality crops at any time. It is a new concept of farming that allows an innovative localized production rationalization in the food supply-chain.
2. **Water saving:** by adopting hydroponics cultivations, TillAge reduces the impact on the consumption of water, reducing it from 85% if compared to traditional farms. As a "waterfall"effect, TillAge reduces the energy consumption resulting from the need to supply water at the place of production, furthermore it consistently contributes in limiting the desertification process of our lands.
3. **environmental impact:** "vertical farming" cuts all logistics and transportation costs and contributes in optimizing energy costs; it reduces fuel consumption, saving precious organic resources for the environment preservation (ca. 90% reduction in fuel consumption, 70% of land subtracted to massive crops).
4. **healthier and safer food:** in a TillAge, the production follows organic and biological criteria to preserve food safety: all our products are certified and immune to contamination (eg. E.coli). The production is always based on the local demand, thus facilitating a scrupulous care in the production processes (-80% of fertilizer).
5. **occupation:** Tillage could employ qualified staff, both in the production and in the selling area. The rise of a TillAge within a district is able to create jobs: the human resources remain local, as local is the demand and the supply for food. Furthermore, TillAge is able to aggregate a series of additional services around the core production and marketing: depending on the structure, TillAge may offer vocational training (agronomy, catering), common/ shared spaces for rent (such as a kitchen or convention areas, or offices), a restaurant useing the crops produced by the TillAge. The combinations are many.
6. **reduction of pollution from fossil:** as there is no need to transport products produced for their distribution, TillAge contributes to drastically reduce pollution from fossil fuel (90% less than conventional farms, which have to distribute their products on the road, rail, sea, air).

How a TillAge works.

TillAge is designed to be placed in the districts of middle-big cities (population density starting from 35K inhabitants).

TillAge can be realized in two ways:

i. through the construction of an ad hoc building
ii. through the restoration of an already existing building (eg, left in a state of neglect, and recovered through the cooperation with the government, both central or local)

The first step toward the realization of a TillAge starts from the identification of an area where to build or of a building to recover. After this first stage, it will be possible to start with the construction or with the recovery process leading to the rise of a TillAge.

A TillAge will host the following areas:

a. production chain of fruit and vegetables
b. marketing and selling
c. additional services

a. Area of production

The production area will affect the 70% of the entire volume of the building and it will extend in a vertical; depending on the size of the TillAge, a specific number of floors of the building will be devoted to the production. This is where specialized staff will take care of the different stages of the production: from planting, to trimming and to harvesting. The production will follow an intensive and constant process throughout the year so that consumers could always benefit from a fresh product h24.

Every day the staff will harvest the product to deliver it to the marketing for the immediate preparation and sale.

b. Marketing and Selling Area

The sales area will affect the most frontal and visual impact of a TillAge, placed preferably at the street level in order to facilitate the access to the consumers. The staff will be in charge of displaying the fruits and vegetables in the exhibition areas, of quality control, of assisting the general public in the selling process, of the preparation and the delivery of crops to local markets, neighborhood stores, small supermarkets chains.

c. Additional Services Area

The area can accommodate Additional Services such as:

- educational spaces to accommodate schools and / or public interested in learning about the innovative methodology of vertical farming;
- restaurants useing home-grown products and organic menus or creative;
- teaching kitchen, rented to third parties or to be used for educational sessions;
- office spaces or for training (plant science, food science, renewable energy, etc.).

Once operative, a TillAge has an average life of 40 years, can cover an area of 4000 square meters (equivalent to 24 hectares of "horizontal" land), guarantees a cycle of continuous cultivation and production throughout the year (each cultivation cycle includes 30 -38 days), could creates new jobs at the local level.

Opportunities on the market (1) — *The Market.*

a) Global Scenario

In 2011, the production of vegetables and potatoes in the EU scores 124 million tons, about 2% on an annual basis. The Third Countries of the Mediterranean represent for the EU a major supply basin, ensuring 42% of the imported volumes.

As regart the Fruit Supply Chain: the production in the EU27 grew by 5% year on year. The main producer countries are: Italy (+3%), Spain (+6%), Poland (+22%) and Greece (+7%), reduced that of France (-1%), Germany (1%) and Romania (-7%).

b) Focus Market: Italy

Vegetable Production chain

The Italian production value is about € 7.2 billion (16% of the total value generated by the national agricultural system), while the turnover of the segment of horticulture "transformation" is around € 5.7 billion (5% of 'whole total turnover of Italian). In 2011: +5%. The annual production is about 15 million tons, while the domestic demand underlines a negative trend over the past five years, with an average annual decline of about 1%, and this trend may be the consequence of the disaffection of the consumer. The average prices have increased by the same amount. The spending represents approximately 11% of the total of the Italians spending for food and beverages, excluding alcohol and tobacco.

Fruit Production Chain

The Italian production value is about 7% of the total value generated by the national agricultural system, with a value at the agricultural stage of about € 3.4 billion; the turnover of the processing industry accounts € 1.1 billion, which corresponds to 1% of total turnover of Italian agri-food market sector.

The annual production accounts 8.5 million tons. The national demand for fruit enhances a negative trend over the past five years, with an average annual decline of 0.2%. This trend may be the result of disaffection with the consumption of fruit by the Italians.

A TillAge business model bases on 3 elements or key-area: 1. Crops production: 70% of the volume of the building extending in vertical; intensive and constant cultivation throughout the year; h24 fresh food to be delivered to the market for the immediate preparation and sale. 2. Commercialization: placed preferably at street level to facilitate the access of consumers; quality control, delivery to local markets, neighborhood stores, small supermarkets. 3. Referral services: spaces for schools and/or public interested in learning about vertical farming;restaurant using home-grown crops or creative teaching kitchen, rented to third parties or to be used for educational sessions; office space or for training (plant science, food science, renewable energy, etc.). A TillAge has an average life of 40 years, can cover an area of 4000 square meters (equivalent to 24 hectares of land "horizontal"), guarantee a cycle of continuous cultivation (30-38 days) and jobs creation.

c) Organic Food Sector Market

The value of the Italian organic food market is approximately € 3 billion, marking the fourth position in the European ranking following Germany, France and the United Kingdom, and the sixth in the world. Italy is one of those European countries not affected by the crisis in the organic sector, or at least maintaining a strong position in times of economic difficulties. This is probably due to the increasing sensitivity of the modern consumer to sensitive themes such as the protection of their health and the respect and preservation for the environment. Both in 2009 and in 2010 the Italian organic market trends showed a more favorable trend if compared to the major countries like Germany, UK, USA and Switzerland. Differently, as regard the per capita expenditure for organic products, Italy is not placed in the top positions in the worldwide and European ranking. Switzerland and Denmark are leading the market, the latter reaches 7% of organic food sells if compared to the total sells of the agriculture market.

Opportunities on the market (2) — *Consumption.*

According to the data (Ismea / GFK-Eurisko), there was an increase in consumption both in 2011 and in the first half of 2012 (about 9% in 2011 and +6.1% in the first half of 2012).

At the same time, an increase in the number of buyers is registered as well as of market penetration, increased from 71.5% in 2010 to 75.5% in 2011. At the national level, there is also an in-progress availability and consumption of a wider range of organic products. In detail, the expenditure for organic packaged food detailed by geographical area, shows that the domestic consumption of organic products in 2011 has focused most, as in past years, in the northern regions of the country, while the Centre and the South in particular, still play a minor role. It remains, however, confirmed the imbalance between production and consumption, historical and typical characteristic of the Italian organic food market.

A consistent decrease in the year 2011 for the fresh-and-processed fruit and vegetables chain (+1%), which remains the most consumed organic category in 2011, with a total value of the organic packaged food just over 30%.

Opportunities on the market (3) — *Distribution and purchase frequency.*

The Mass Retail Channel is the preferred channel for the purchasing organic products, including fruit and vegetables. Depending on the further segmentation of the organic target group (high, medium, low, occasional), it is possible to identify different frequencies of purchase:

1. the so-called “high buyers” usually purchase every two weeks (contributing to the 42% o the organic market packaged’s value in the Mass Retail Channel);

2. the so-called “average buyers” usually buy at least eleven times a year and almost once in a month (contributing nearly to the 27% of the organic market packaged’s value in the Mass Retail Channel);

3. the so-called “low buyers” usually purchase seven times (once every two months; contributing nearly to the 16% of the organic market packaged’s value in the Mass Retail Market)

4. the so-called “occasionals” usually purchase once every four months (contributing around to the 15% of the organic market packaged’s value in the Mass Retail Market).

Besides the “organic consumer”- much more inclined to purchase a product causing a “zero impact” on the environment as well as biologically safe and certified - TillAge will also focus on a wider and horizontal target group of consumers, who are encouraged to (daily) purchase vegetables and fruits by competitive prices if compared to those offered by the existing market. The potential customers of TillAge are well distributed both at European and global level; in fact, the highest concentration of customers of the organic sector market is located in Switzerland, Denmark, Germany, the United Kingdom, while Italy is not placed immediately behind the front runners. The need to find solutions to feed of food and water the world's population is indeed confirmed by studies developed worldwide by the most important local and central government organizations.

Opportunities on the market (4) — *Proof of concept.*

Vertical Farming is already and existing and successful reality in many countries of the world, addressing the issue of Urban Agriculture according to different approaches and solutions.

The most relevant "proof of concept" of Vertical Farming comes from Sweden, where a "plantscraper" is rising where Plantagon is going to produce mainly leafy vegetables (salads) habitually consumed by the Asiatic countries, with the greatest concentration of population density at present time.

The Asian market is indeed strategic: most of the "megalopolis" is currently located in Asia, where the concentration of population is constantly increasing and where the demand for food and water will become truely primary and emergent in the near future.

Tillage, however, has a different approach: instead of focusing on big plantscrapers, it rather bases on a “local” concept, aiming at developing urban district plantations. In "locality" lies TillAge strenght and competitive factor, able to satisfy a local need and at the same time to create jobs and benefits for the community.

Target Audience.

The potential target groups can be classified as follows:

(i) consumers (in particular the organic segment);

(ii) restaurants, bar, snack bars;

(iii) retailers (small fruit and vegetable shops, local markets or itinerant street vendors);

(iv) Mass Retail Market

(v) educational bodies

(i) **Consumers:** it is a very large target group including all age and gender groups, as well as the consumers of organic foods market field.

Qualitative data: the consumption of fruit and vegetables is more evident in women (particularly the youngest age group); as regard children, consumption is good in preschool-period and then it decreases in the school period and during adolescence. In adults, however, an inverse process is observed: the consumption of fruit and vegetables increases with age.

(ii) **Restaurateurs, bar, snack bars, bistro:** each district, be residential or business, includes restaurants, bars, bistro serving both local and surrounding area customers. It is a target who daily or weekly needs to supply of fruit and vegetables for food preparation so TillAge would play an added value as it is able to offer daily fresh products, at competitive costs, taht could also be purchased in small quantities as needed.

(iii) **Retailers (small fruit and vegetable shops, local markets or itinerant street vendors):** This is a target finding a real added value in proximity and in competitive prices, since its activity is closely linked to the local dimension (reference district or neighborhood). The opportunity to refer to a trusted local point of sale, offering fresh high quality products, allows small businesses or local markets of supplying of fresh products quickly, just around the corner and yet directly from the producer.

(iv)**Mass Retailers Market:** nowadays, each district can offer at least one small / medium size Mass Retailer Market. This target group might find in TillAge a competitive supplier of fruits and vegetables, or a potential partner for the realization of a Till-A module (rooftop module, ie on the roof of the store) that would facilitate a local production to be directly sold in the point of sale below.

(v) **Educational bodies:** This is a potential target group interested in TillAge in two potential ways: a) primary and secondary schools located in the district interested in providing their students with in-depth application modules on topics such as environmental sustainability, social inclusion, nutrition and science, b) higher education institutions, universities, VET centers interested in delivering sector skill courses on topics related to the technologies of construction, LED lighting, plant science, eco-sustainable building technologies.

Competitive Scenario.

The traditional cultivation represents the actual competitive scenario, both in the open field and in greenhouses.

There are a few existing projects of urban farming and vertical farming developed in the United States, Sweden, Japan, China, South Korea, while only research studies can be traced in Italy so there seems to be no direct competitors at national level.

The European experience can be traced in the Plantagon project, coming from Sweden, which consists of the development of an impressive plantscraper for the production of food (mainly salads) for Asian populations.

Competitive Advantage

The current agricultural crops are totally dependent on fossil fuel. This dependence on these kind of resources probably run out in the next thirty years, represents a strong risk for the world's population and their maintenance. The innovative approach of TillAge is the resulting combination of 3 key factors:

(a) **verticality:** the surface turns to vertical, facilitating the position of TillAge within the urban district, enhancing the value of local demand and supply as well as contributing to the rise of a true "smart city."

(b) **technology:** TillAge applies the newest technologies in the field of:

(b)1. construction and materials (galvanized steel frame and glass panels for TillA-Module, refrigeration system/humidification, artificial LED lighting system, recirculating hydroponic cultivation system);

(b)2. of cultivation (hydroponics and aquaponics methods, ie without soil but through artificial panels where the crops are plugged, fed through a system transporting nutrients by water recirculation, enriched with nutrients; aquaponics, where the nutrients for the growth are "produced" by freshwater fish through their droppings, in an ecosystem entirely self-sufficient; aeroponics, plants are placed in special boxes without soil and fed through a misting system further optimizing water consumption);

(b)3. energy savings (by the extraction of methane derived from compost to generate energy for the lighting and for keeping the environment warm; photovoltaic panels placed on the roof or directly applied to the glass panels of the Tilla-Module structure);

(c) **proximity:** it determines a new way of production and distribution of fruit and vegetables.

Tillage determines a new style in the production and distribution of fruit and vegetables. Positioning within neighborhoods, it could optimize the production by offering a h24 fresh product, with high-quality standards, producing the amount of food basing on the real needs of the potential buyers of the district. This same proximity has a positive impact on pricing policies: by cutting the costs of supply chain, ie, processing and transportation, all consumers can buy at very competitive prices, which are not affected by fluctuations caused by the rising of fuel or by special seasonality conditions or by climate disasters. The "local" position of TillAge also facilitates a positive dynamic within the market, using local human resources and generating a wider welfare for the community.

Innovation and Technology.

Tillage is a revolutionary new way of farming. If compared to traditional methods, and by using technologies applied to construction, agronomy, energy-saving, artificial lighting systems, Tillage® can:

- offer crops at a much lower cost: consumers can afford to buy locally safer and genuine products, just around the corner
- produce crops with a high nutritional value, quality guarantee and safe yet without sacrificing taste: the cultivation follows organic criteria, no added pesticides or chemical fertilizers are used, so that fruits and vegetables are harvested only when they are fully ripe, for their immediate consumption
- offer a strong and positive social/environmental impact, creating new jobs, recruited locally and which stays local: local people play an active role in TillAge process not only just as consumers, but as a resource to be used in the manufacture and marketing processes. Tillage may also contribute to the recovery of derelict land and the creation of new centers of social aggregation, stimulating a new environmental consciousness (reduction of energy consumption, of fossil hydrocarbons, of water consumption, of health risks, of the intensive and extensive usage of the agricultural lands). The scalability of the project is guaranteed just by its local feature, but with a strong application potential on a "glocal" level
- completely "oil free", ie. not dependent on fossil fuel for cultivation, processing and transportation and sheltered from adverse climate conditions, it can ensure the supply of fruits and vegetables in a consistent manner throughout the year: being completely "oil free", ie not dependent on fossil fuel needs for cultivation, processing and transportation of the product and sheltered from adverse weather conditions or catastrophic, Tillage can guarantee continuous production, lower prices, continually satisfying the market demand. Tillage cultivation process is really intensive, getting the maximum yield per acreage: 1 indoor acre is equivalent to 4-6 outdoor acres or more, depending on the crop variety (in the case of cultivation of carrots, for example, the average yield is 200 / 400 quintals per hectare).

State of the art.

At present time we are fixing a few exploratory relations for collaboration on the project with some of the most important global experts on Urban Agriculture and Vertical Farming: Plantagon (Sweden), Innovation Network (Netherlands), PlantLab (Netherlands), Fraunhofer (Italy / Germany) and EURAC (Italy). We are about to develop an Executive Plan for the development of the TillAge pilot.

References.

- A. Ikeda, Y. Tanimura, K. Ezaki, Y. Kawai, S. Nakayama, K. Iwao, K. Kageyama, “Environmental Control and Operation Monitoring in a Plant Factory Using Artificial Light.” Acta Hort 304 - 1992
- M.H. Jensen, "Hydroponics." Hortscience, Vol. 32, Issue 6 http://ag.arizona.edu/PLS/faculty/MERLE.html - 1997
- G. Wilson, “OH-Farms–Tropical Greenhouse Growing.” Hydroponics and Greenhouses 51 - 2000
- A. Worsley, “Nutrition Knowledge and Food Consumption: Can Nutrition Knowledge Change Food Behavior?” Asia Pacific Journal of Clinical Nutrition 11, no. 3 - 2002
- Grunert, K.G. “Food Quality and Safety: Consumer Perception and Demand.” European Review of Agricultural Economics 32, no. 3 - 2005
- A. Heiney, "Farming for the Future." NASA http://www.nasa.gov/missions/science/biofarming.html - 2006
- G. Thiyagarajan, R. Umadevi & K. Ramesh, "Hydroponics," Science Tech Entrepreneur, Water Technology Centre, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu 641 003, India - January 2007
- J. Fehrenbacher, "Mickey Mouse Sustainable Farming at Disney Epcot." Inhabitant - http://www.inhabitat.com/ - 2007
- D. Braithwaite, "Pot Bust A Family Affair." Sydney Morning Herald. http://www.smh.com.au/news/national/pot-bust-a-family-affair/2006/07/18/1153166349925.html - 2008
- L. Chamberlain, "Sky Farming." New York Magazine. http://nymag.com/news/features/30020/ - 2008
- S. Crupi, "Metro Makes One of Largest Marijuana Busts in Recent Years." News 3 http://www.kvbc.com/Global/story.asp?S=3487528&nav=15MVbAvi - 2008
- Dr. Anthony Glass, "Inorganic Plant Nutrition: The Essential Elements and their Functions."University of British Columbia http://www.botany.ubc.ca/biol351/351.htm - 2008
- Indianetzone. "History of Hydroponic Gardening". http://society.indianetzone.com/gardening/ - 2008
- K. Murphy "Farm Grows Hydroponic Lettuce." Observer Online. http://www.observernews.com/stories/current/news/120106/Lettuce.shtml - 2008
- K. Roberto, "How-To Hydroponics." http://www.howtohydroponics.com/ - Date Unknown. (September 18, 2008)
- Time Magazine Editors. "Hydroponics." Time Magazine. March 1, 1937. http://www.time.com/time/magazine/article/0,9171,757343,00.html (September 18, 2008)
- Time Magazine Editors. "Hydroponics To Wake." Time Magazine. May 23, 1938. http://www.time.com/time/magazine/article/0,9171,882955,00.html?iid=chix-sphere (September 18, 2008)
- Bareroots Hydroponics . http://www.living-learning.com/faq/homebflo.htm 2009
- "Growstones ideal alternative to perlite, parboiled rice hulls". American Society for Horticultural Science http://esciencenews.com/articles/2011/12/14/growstones.ideal.alternative.perlite.parboiled.rice.hulls - 2011
- B. Wallheimer, "Rice hulls a sustainable drainage option for greenhouse growers". Purdue University - 2012
- M. Böhme, J. Schevchenko, I. Pinker, S. Herfort, "Cucumber grown in sheepwool slabs treated with biostimulator compared to other organic and mineral substrates". ISHS Acta Horticulturae 779: International Symposium on Growing Media - 2012.
- SF Alshammary, "Aquaponic method and apparatus for use in arid environments" - Google Patents - US Patent 8,176,875, 2012
- J. Carver, B Wasserman, "Hands-On Hydroponics" - The Science Teacher, digital.nsta.org - 2012

- H.M. Resh, "Hydroponic Food Production: A Definitive Guidebook for the Advanced Home Gerdener and the Commercial Hydroponic Growner" - 7th Ed. - 2013
- A Assimakopoulou, A Kotsiras, K. Nifakosa, "Incidence of Lettuce Tipburn as Related to Hydroponic System and Cultivar" - Journal of Plant Nutrition, Taylor & Francis - 2013
- Z. You, X. Zhang, C.-H. Chen, K. Ono, H. Hibino, S. Koyama, "Impact of Relevant Knowledge on Purchase Intention of Plant-factory-produced Plants. Case Study in Both Singapore and Japan" - Focusing on Modern Food Industry (FMFI) - 2013