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WHITEPAPER


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Contents

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Executive Summary

The Liquid Nano Clay (LNC) is proprietary innovation of Desert Control which enriches desert sand to fertility levels comparable to high quality farming soil — with a lower irrigation requirement and potentially higher crop yield. LNC operates by producing an optimal mixture of sand and clay that provides a moisture holding and yet airy soil. This process, which otherwise is very time consuming with mechanical equipments, takes only a few hours with LNC. Furthermore, LNC covers the surface of each individual sand grain with nanoparticles, while the old mechanical mix method just fills the gap between the sand particles and requires 10 times as much clay.

The LNC technology was originally developed in 2008 and has since been undergoing commercial assessments through laboratory and field trials. As a follow up to field tests in Egypt, China and Pakistan, the product was tested on a farm located in the UAE, to facilitate an entry into the Middle East market. This report highlights the methodology, and results of this field test.

The test was carried out on a 800 m^2 area within the premises of an existing farm located in Al Ain, Abu Dhabi, UAE. Sweet sand spread across the whole area was treated with a layer of chicken manure (approx. 0.5 kg per m^2), and half of the total area (400 m^2) was subsequently treated with LNC. To examine the effect of LNC on the yield of different vegetables, both areas were cultivated with the same quantities of cauliflower, okra (ladies' fingers), sweet peppers, and carrots for a period of 3 months (between 28th of November, 2017 and the 5th of February, 2018). During the cultivation periods, less water was applied in the regions where LNC was applied, in order to assess the water saving potential of LNC. The volumetric water content (VWC) and temperature measurements at the root level of the cultivated plants were monitored during the experiment, since they have a strong influence on the optimum irrigation schedule.

Results show that the average weight of the heaviest piece of cauliflower, okra, sweet peppers and carrots, harvested from the area treated with LNC, was higher by 109 %, 18 %, 64 %, and 17 %, respectively. Based on the VWC and temperature measurements at different soil depths, LNC allows for a reduced irrigation demand while maintaining the roots at temperatures equivalent to those of the control areas.

While these results portray an undoubted superiority of the generalized LNC mix for cultivating cauliflower, subsequent tests are required to optimize the mix ratio, materials and watering schedule for other crops. Watering quantities and schedules have to be optimized for the different seasons in the region. A technical evaluation of the VWC and temperature indicate that optimum irrigation would be to irrigate at the lowest soil surface temperature and irrigate to keep the VWC within 5 to 10%. This indicate optimum growth and optimum water savings potentials.

Problem

Deserts

Deserts constitute an estimated one-third of the earth's total landmass.[1] This has a direct consequence of food insecurity, poverty, unavailability of water and low biodiversity. Habitats of these regions have to derive food overseas, and this increases the carbon footprint of their diet. There are currently no commercially viable and sustainable solutions to this problem.

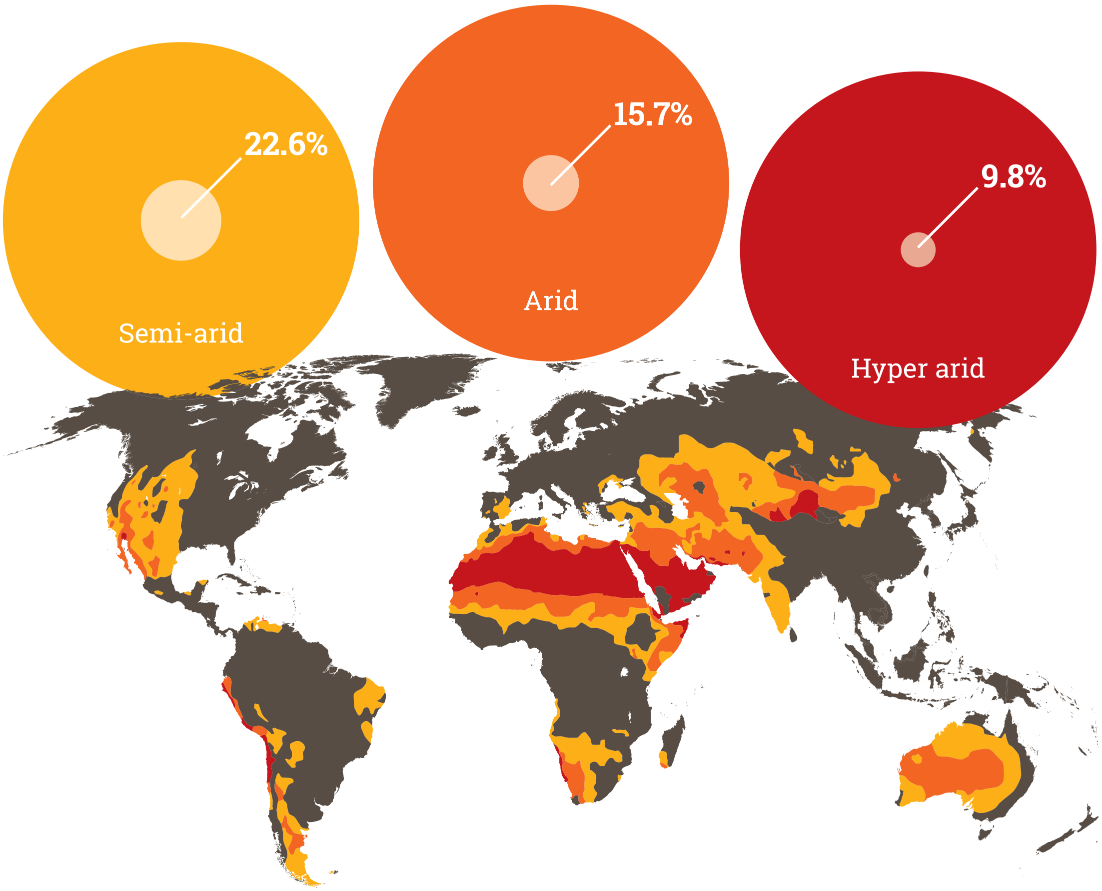

Figure 1. The figure shows the spread of the different categories of desertlands around the world.

Desertification

In addition to the vast reach of deserts, desertification —the turning of fertile land into deserts—is an environmental issue that is now affecting 168 countries across the world, and costing US$ 490 billion per year.[2] While the economic impact of desertification is by itself telling, the social dimension of the problem is even more serious — the problem completely alters how people socially relate with their environment.[3] Primary stressors involved with this problem include hunger and forced migration, with about 15% of the total migrants worldwide being environmental migrants.[4] There are currently no confirmed cause-effect processes that lead to desertification.

1 *http://www.un.org/en/events/desertification_decade/whynow.shtml*
2 The Guardian. "Desertification crisis affecting 168 countries worldwide, study shows": https://www.theguardian.com/environment/2013/apr/17/desertification
3 Thomas, D. S. (1997). Science and the desertification debate. Journal of Arid Environments, 37(4), 599-608
4 Leighton, M. (2016). Desertification and migration. In Governing global desertification (pp. 63-78). Routledge.

Solution

Liquid Nano Clay offers:

Soil Fertility

The LNC treatment creates an organic network perfect for plant growth. As such, when applied to desert sand, the crop yield of the sand is increased by up to 40%. This directly results in a higher yield of crops cultivated on the desert soil.

Water savings

The network created by LNC retains water more effectively than desert soil, offering a water saving of up 65%. This results in less water requirement in farms. Considering that water is typically more costly in desert regions, such water savings translate to a huge cost reduction for the farmers.

Natural product

LNC is made from completely natural ingredients which facilitates its complimentary effect on other fertilizing or farming methods. The mixing technology ensures uniform application, and the possibility to apply LNC in a large, extended area.

The LNC Treatment

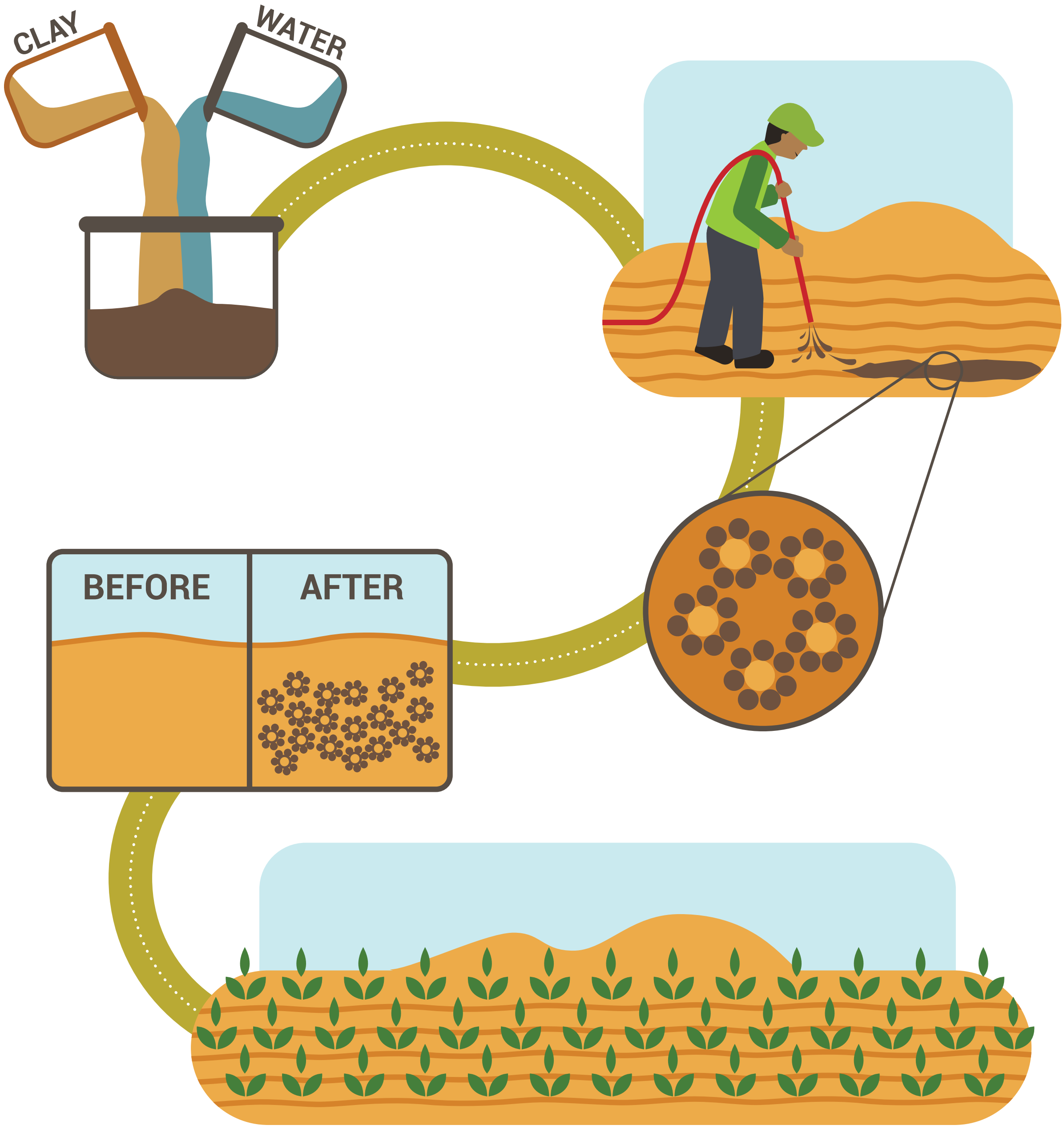

Figure 2. The figure shows the process flow for the LNC treatment of farmlands. Mixing can either be off or on-site and the spray application can be applied using any conventional farm spraying equipment.

Key invention component. Our invention is a novel technique of effectively mixing clay with water in a way that ensures the clay particles are perfectly distributed at the surface of each individual sand grain, to create complete envelopes around each grain. This mixing technique produces the ideal soil with a perfect mix of sand and clay, with the LNC covering the surface of each individual sand grain with the nanoparticles — just enough to adequately retain moisture and yet allowing for good ventilation. Thus, upon application of LNC, the sand turns into a sponge-like fabric that retains moisture/water and nutrients for a longer period of time. Consequently, LNC treated farmlands will require less water for irrigation, and cultivated crops are exposed to a higher quantity of nutrients — for an overall higher yield.

Study Area

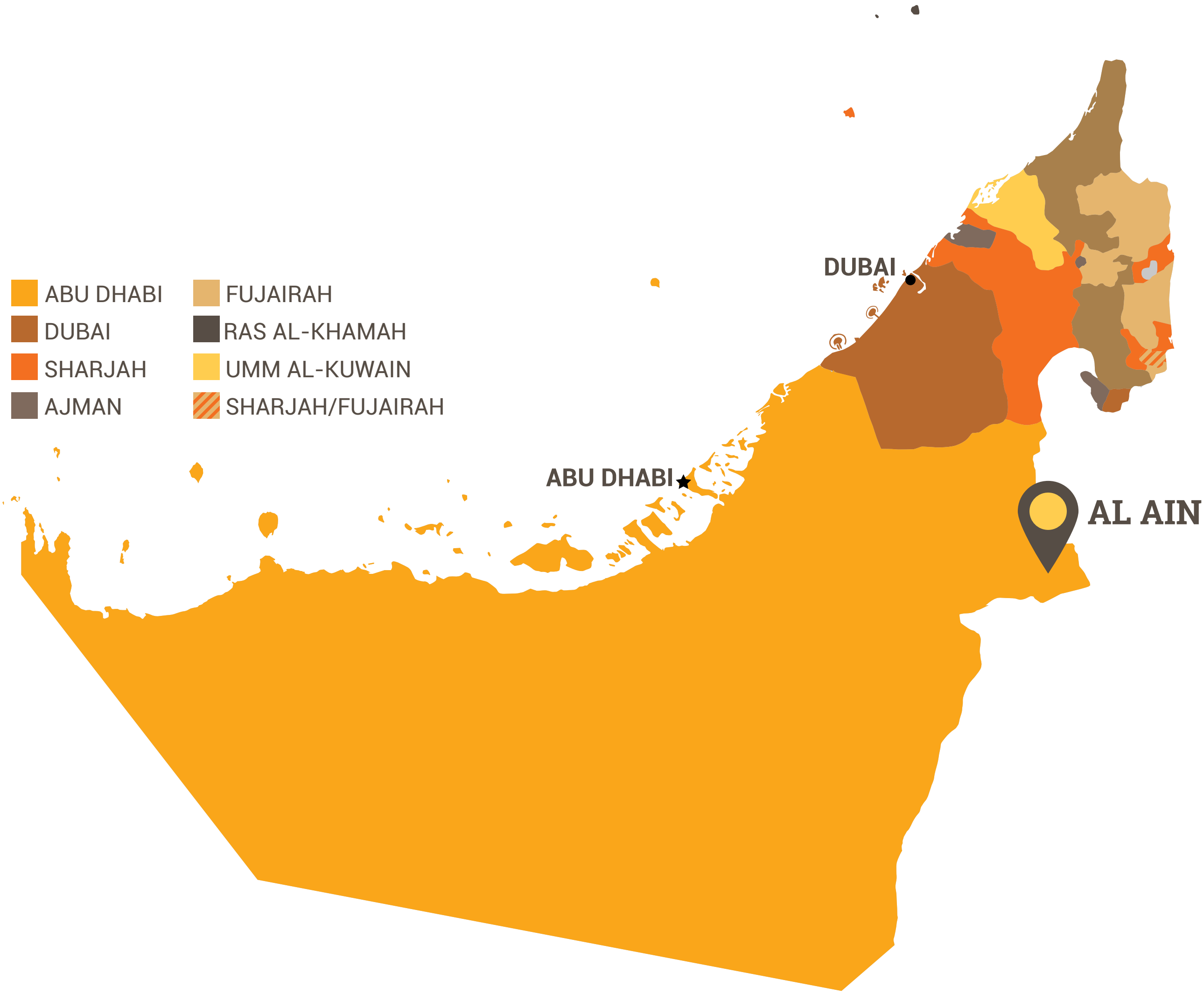

Figure 3. Location of the test site within the United Arab Emirates.

The study was carried out on a farm located in Al Ain, Abu Dhabi, United Arab Emirates. Al-Ain is a town in the Emirate of Abu Dhabi located in the eastern part of the UAE. It is geographically located approximately 160 km east of the capital town Abu Dhabi and about 120 km south of Dubai. The eastern part of Al Ain spans over about 13,100 km^2. Oman lies to the east, Dubai and Sharjah to the north, Abu Dhabi to the west and the Empty Quarter desert and Saudi Arabia to the south. The city has a hot desert climate, featuring long, extremely hot summers and warm winters. In Al-Ain, the average relative humidity ranges from a low of about 20% in the summer months, to a high of about 60% in the winter months.[1]

The study area, which is within the wider Arabian Peninsula, is considered water scarce due to its hyper-arid climate conditions. Average annual precipitation is less than 100 mm, while potential evaporation reaches 2500 mm in coastal areas. [2] In the central parts of the Rub' Al-Khali desert, this number could be as high as 4500 mm per year -- due to the significantly lower air humidity in comparison to the coast.[2]

1 https://www.worldweatheronline.com/lang/en-us/al-ain-weather-averages/abu-dhabi/ae.aspx
2 Z.S. Rizik et al."Water resources in the United Arab Emirates" Developments in Water Science, 5(2003): 245-264. https://www.sciencedirect.com/science/article/pii/S0167564803800229?via%3Dihub

Al Ain Test Methodology

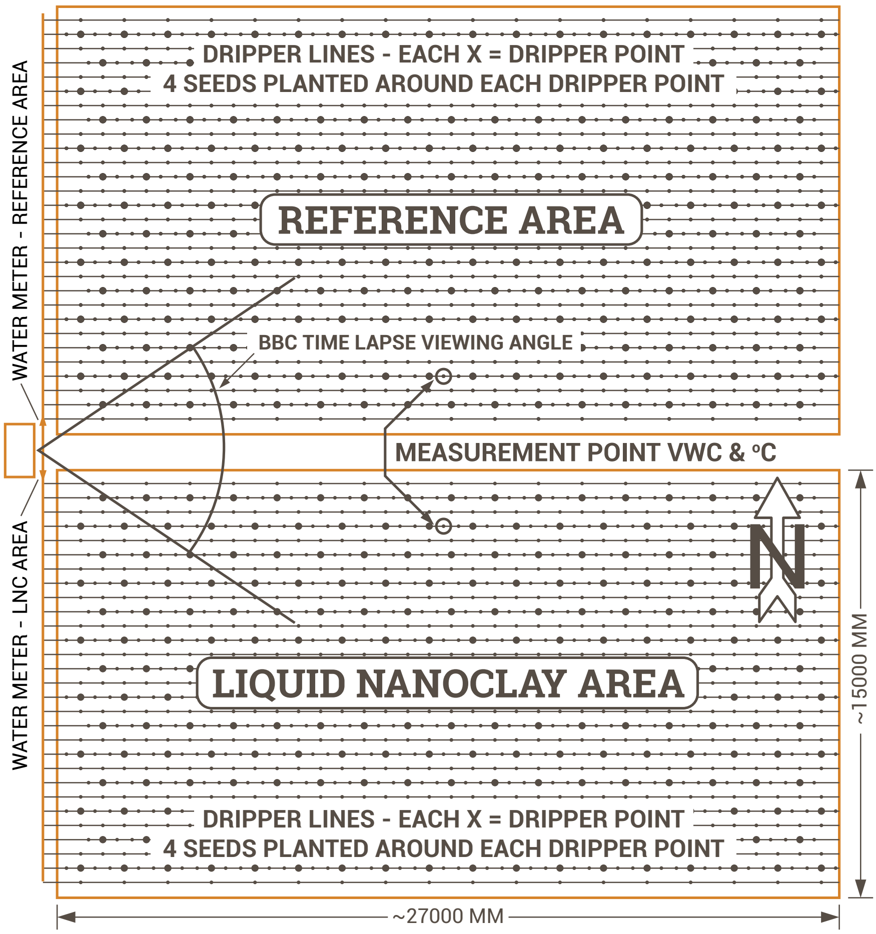

Figure 3. The figure shows a scheme of the test area. Dripper areas are marked with "x". 4 seeds are planted in each dripper point in both the reference and LNC treated areas.

Period. The experiment was divided in three main time frames according to different irrigation schedules for the LNC area. These time frames spanned across the following periods: (1) 09/12/17 - 15/12/17; (2) 15/12/17 - 21/12/17; (3) 21/12/17 - 07/01/18; (4) 07/01/18 - 04/02/18.

LNC mixing. LNC was mixed offsite at ambient temperature and pressure.

LNC application. After application of chicken manure (Al Yahar), LNC was injected to a depth of approximately 75 cm, using a rigid pipe connected to the end of a spray hose and inserted into the ground (see Fig 4.). Injection sites were ensured to always coincide with the position of the drip irrigation nozzles.

Root humidity and temperature measurements. VWC sensors were placed at depths of 10, 20, 30, 40 and 60 cm below the ground surface, while temperature sensors were placed at depths of 5, 15 and 30 cm. Both types of sensors were placed at locations around the irrigation nozzles. Humidity and temperature data were collected every hour and uploaded via a data logger.

Watering schedule. During the whole experiment, the reference area was watered twice a day (morning and evening), while the LNC area was watered only once a day, once every second day and once every third day, during the 1st, 2nd, and 3rd periods respectively. The overall water consumption was measured through flow meters connected to the main supply pipe of each drip irrigation field (see Fig 5).

Figure 4. The figure shows the application process of LNC.

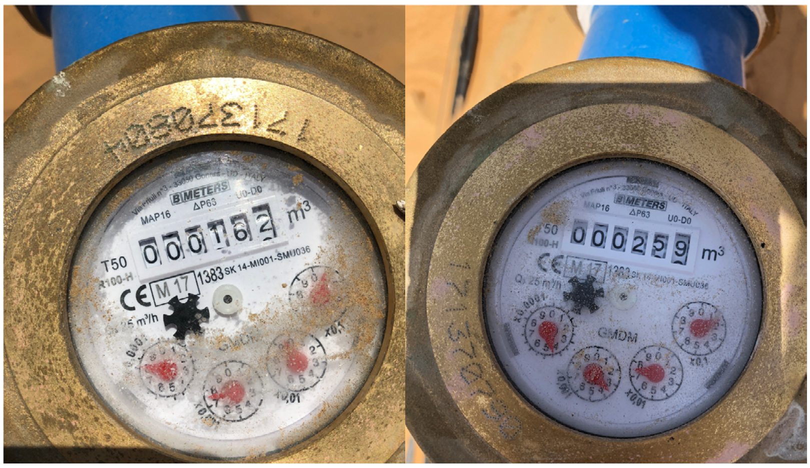

Figure 5. The figure shows the flow meters used to measure overall watering rates. Left: water level of LNC region. Right: watering level of control region.

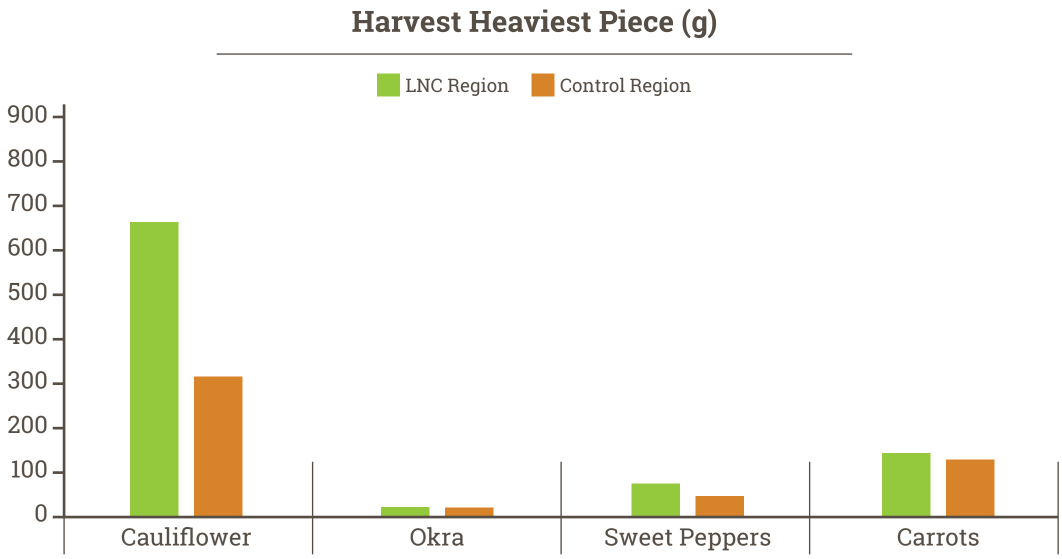

Figure 6. The figure shows a bar plot comparing the heaviest piece of harvest from the LNC treated region and the control region.

Results

Upon harvest, the weights of the individual crops were recorded as harvested from the LNC treated and control regions. Fig. 6 shows a comparison between the heaviest crops harvested from both regions — an indicator of the average weight of each harvest. Based on the data collected, the LNC area produces larger individual harvests (see Fig. 6). The heaviest cauliflower from the LNC region weighed 773 g (see Fig.7) while that from the control region weighed 369 g (i.e. less than half). There was no significant difference between the heaviest okra from the LNC and the control regions (LNC:20 g; control:17 g). The heaviest sweet peppers and carrots from the LNC region weighed 72 g and 157 g respectively, while those from the control regions weighed 44 g and 134 g, respectively.

LNC shows thus undoubted promise to improve the yield of cauliflower even under reduced water consumption. Further experiments are required to optimize mixing and cultivation parameters for okra, carrots and sweet peppers. Subsequent studies will investigate other vegetables common in the region.

Figure 7. Left: the heaviest piece of cauliflower on a weighing balance. Right: a length comparison between the heaviest piece of carrots from both regions of the farm.

To further investigate the water retention capacity of LNC, temperature and humidity sensors were systematically placed at various soil depths in both the reference and LNC areas. Data collected during this test are segmented into four different periods with varying watering schedule. The periods and their corresponding watering schedules are shown in Table 1.

Reference area	LNC area
9 - 15 December 2 cubic meters of water every day	**9 - 15 December** 2 cubic meters of water every day
15 - 21 December 2.3 cubic meters of water every day	**15 - 21 December** 1.2 cubic meters of water average per day
21 December - 7 January 2.7 cubic meters of water every day	**21 December - 7 January** 0.6 cubic meters of water average per day
7 January - 4 February 2 cubic meters of water every day	**7 January - 4 February** 1.3 cubic meters of water average per day

Table 1. The table shows the four different test periods and their corresponding watering schedules for the reference and LNC areas. The bars represent the quantity of water introduced to the soil each day.

Period 1

Period 2nd to 9th December

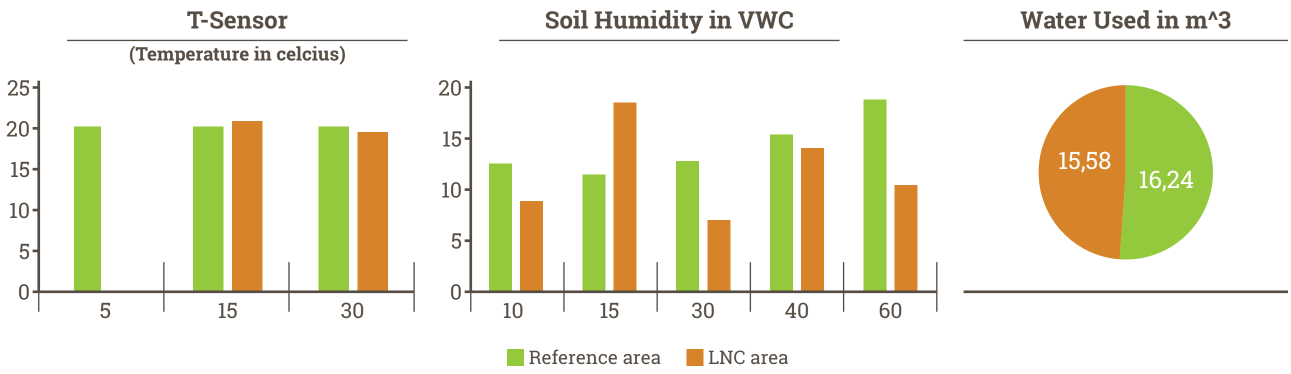

Figure 8. The figure shows the average soil temperature, and VWC as a function of soil depths (cm), and the total quantity of water used, during the test Period 1. The LNC area temperature value at a soil depth of 5 cm is omitted due to failed equipment.

During the test Period 1, the watering schedule and quantity across both areas were equal, hence there was no significant difference in soil temperature (see Fig. 8). However, while a linear increase of VWC with depth is observed in the reference area, in the LNC area, there is a spike in VWC at depths of 20 cm and 40 cm. The linear increase in VWC in the control area depicts how the top soil surface is more exposed to evaporation rates from the water table — typically in the range of 2500 mm/year.[1] On the other hand, spikes at depths of 20 cm and 40 cm demonstrate the water holding capacity of LNC at these depth levels. Comparing the VWC from both areas also suggests that the plants have their main water consumption at a depth of 30 cm. As such, the irrigation water percolates down, and the evaporated portion shows some condensation /LNC absorption in the 60 cm depth. Similar trends were observed in the field tests conducted in Egypt.

Period 2

Period 15th to 21st December

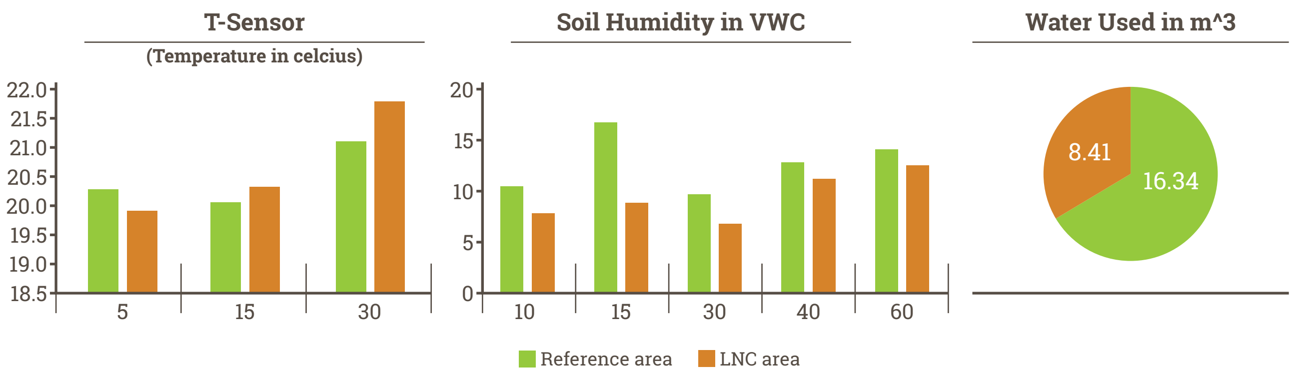

Figure 9. The figure shows the average soil temperature, and humidity as a function of soil depths (cm), and the total quantity of water used during the test Period 2.

Soils in both areas are observed to be roughly of the same temperature during the test Period 2 despite the lower (halved) watering quantity and frequency in the LNC area, as shown in Fig. 9. VWC in the reference area portrays some linearity with depth. However, this time, there is a spike in VWC at a soil depth of 20 cm. This could indicate overwatering and a saturation of the absorption capacity at the top layers of the soil. In contrast, as expected, the LNC area shows a somewhat constant VWC across all depths, with a slight deep at the 30 cm depth level — substantiating the claim of the plant's root obtaining its water at that level.

1 A.A. Murad. "An overview of conventional and non-conventional water resources in arid regions: assessment and constrains of the UAE. Journal of Water Resource and Protection. 02(02): 181-190. https://www.scirp.org/journal/PaperInformation.aspx?PaperID=1327

Period 3

Period 21st December to 7th January

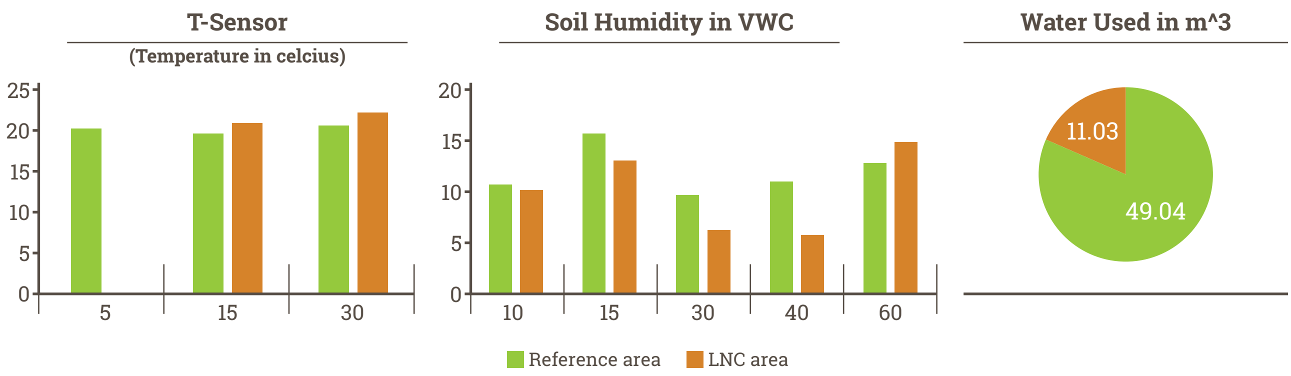

Figure 10. The figure shows the average soil temperature, and humidity as a function of soil depths (cm), and the total quantity of water used, during the test Period 3.

Figure 10 shows that temperatures measured during the test Period 3 are merely constant despite a 77.5 % lower irrigation quantity and frequency (watering ratio of about 1:5). During this period, both VWC plots show rather high VWC levels at 20 cm depth suggesting an overwatering scenario.

Period 4

Period 22nd January to 4th February

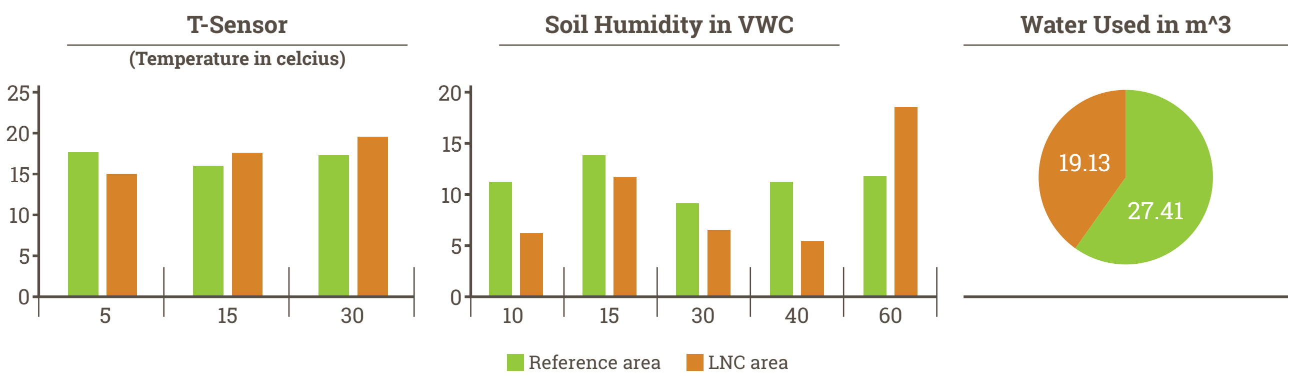

Figure 11. The figure shows the average soil temperature, and humidity as a function of soil depths (cm), and the total quantity of water used, during the test Period 4. Note that data from 7th-22nd of January were lost due to some technical failures.

Test Period 4 maintains the constant temperature trend displayed in the previous periods, while the VWC values are similar to test Period 3 (see Fig. 11). The relatively high VWC at a soil depth of 60cm in the LNC area suggests the absorbance of water by the LNC layer from the ground water table.

Conclusions

Features of LNC

The ability of LNC to increase yield, while reducing irrigation requirement by up to 77.5 %, has been validated by the collected test data. Such capacity of the LNC is based on its ability to hold water for a long period of time to maintain the optimal soil VWC conditions.

Lessons Learned and Irrigation Scenarios

Period 1-4 show different irrigation regimes. Period 3 was closest to an optimum irrigation regime.

The irrigation schedule have to be optimized for different crops. Further studies will investigate the applicability of low water quantities delivered in shorter intervals for a more evenly distributed soil humidity profile. Temperature and VWC sensor data will be explored as an input for controlling the irrigation systems — using a automatically controlled feedback loop — in order to establish optimum irrigation regimes. The optimal regimes will then be prescribed to customers for subsequent use without the feedback control loop.

Futhermore, optimization studies have to be carried out for various mixtures and application techniques, soil irrigation depths, and the irrigation schedule for different air humidity levels.