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The solution to soil degradation

September 2022

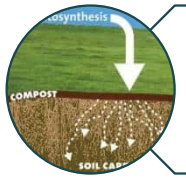
Soil degradation, a huge problem threatening global food production

The world can run out of topsoil in 60 years.
33% of soils degraded, increasing rapidly.

Resistant weeds and soil-born pathogens are hampering global food production. **59%** of farmers fields in US are now affected, increasing rapidly.

460 active ingredients now banned, EU Green Deal target a further 50% reductions. **=>Farmers are left with few or no alternatives.**

Organic farming problem: **10%-40%** lower yield than conventional farming, do not produce enough food with current practice



Soils store more carbon than the atmosphere and all the world's plants and forests combined.

Sources: FAO, Global assessment of soil pollution report, 2021.

More than 4 million tons of pesticides ends up in the soils yearly.

The amount of soil taken out of circulation due to invasive alien species or diseases increases

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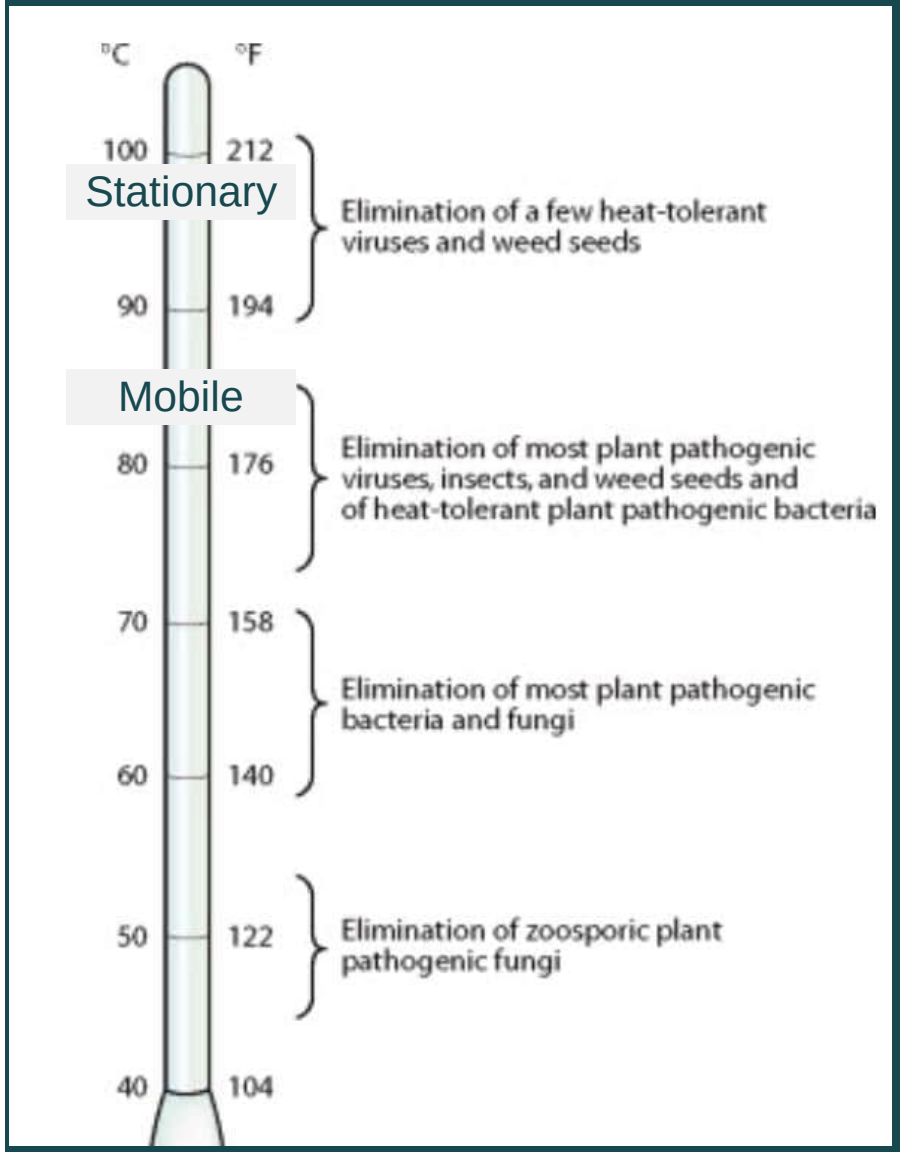
Soil steaming is an old technology

Steaming has been used to fight weeds and pathogens for more than 100 years.

Soil steaming went out of fashion in the 1960s when efficient pesticides took over the market.

Slow machines and high cost have prevented a wide-spread use of the technology.



GEORGE N. AGRIOS, in Plant Pathology (Fifth Edition), 2005

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SSI is targeting the market with two different product offerings

Mobile unit

Mobile machines, treating soil **in farm fields, reducing** weeds and pathogens

Stationary unit

Stationary machines, treating soil **on-site, removing** weeds, invasive alien species and pathogens

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Case 1: Carrot producer in Norway

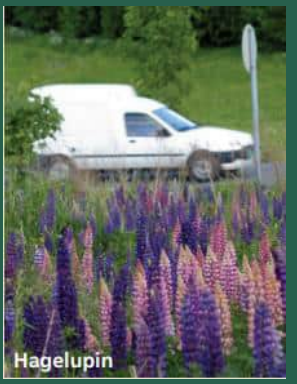
- Carrot is the main vegetable produced in Norway with a production volume of 55 million kg/year.
- Farmer had severe problems with soil-born pests, around 40% of crop destroyed.
- Infected areas increased year by year
- No chemicals available to treat pest problems

Case 2: Flower producer and park owner in Oceanside, CA

- Severe problems with pests
- Has to use chemicals today, but cannot use it close to houses
- His major concern is negative publicity in social media (chemicals => cancer)
- High income per hectare, ability to pay for solution is high

Case 3: Road building contractor in east-Norway

- Heavily infected soil, Potato Cyst Nematode, survives in soil for 50 years
- Large areas with invasive alien spices
- Huge amount of soil transported to landfills.
- Strong political and economical incentives to find alternative solutions

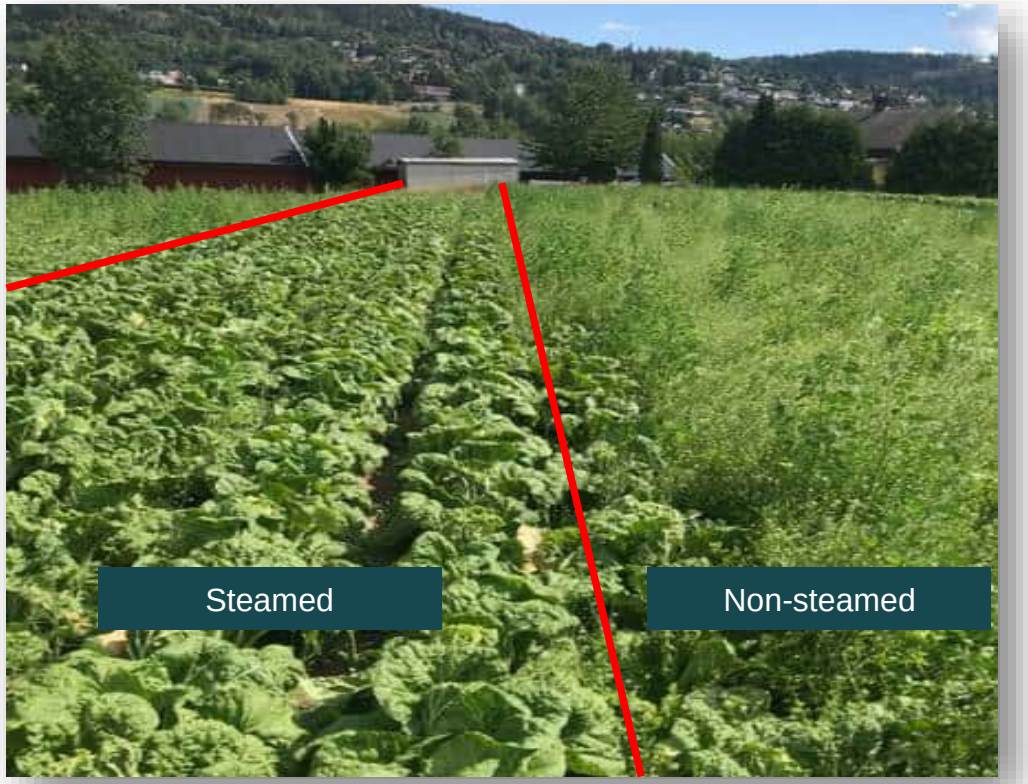


Steam removes weed, reduces harmful organisms, and increases yield

SSI full-scale test demonstrated 330% (!) yield increase with respect to control field with pesticides, 180% yield increase with respect to normal average yield for parsley rot in this part of Norway. Numbers verified by 3rd party (NLR).

Better growth of parsley root in steamed area due to release of nutrients, no competition for nutrients, and no harmful attacks on crop.

Picture from SSI tests in 2021.



Weed problems eliminated by steam in Chinese cabbage field.

Picture from SSI tests in 2019.

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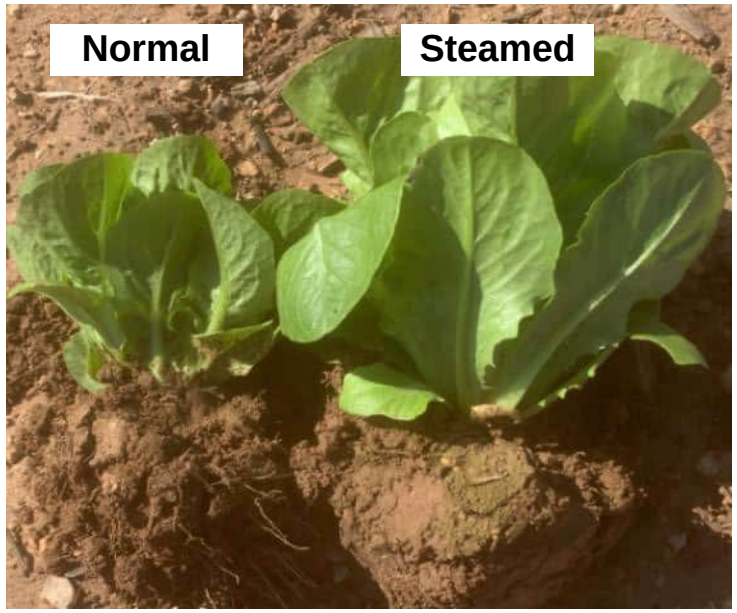
Trials show superior growth in steamed soil



Results from SSI trials in Spain fall 2021

Customer is Gs, one of the largest fresh producers in Europe

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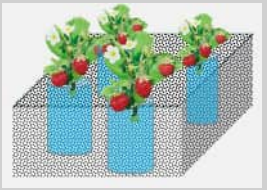
SSI will make steaming a universal farming practice, being a competitive and attractive solution to farmers soil health problems

Operational inefficiency and high cost have historically prevented widespread use of steam

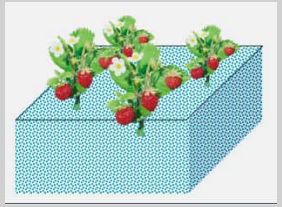
Precision steaming → Advanced process control → Multi-farm usage → Semi-autonomous driving → 24/7 continuous operation

Width unique technology and features, SSI is targeting **75%** cost reduction and **5 times faster** steaming compared to mobile steam competitors

Blue volume steamed



SSI Precision Steaming



Competition

SSI prototype evolution of mobile machine

Prototype 1. Demonstrating we can make steam work.

Prototype 2. Patented technology shows good results applied in larger fields.

Prototype 3. 16 hours a day full steaming season in Norway and Spain. Still not efficient enough.

Prototype 4. Steaming cost and efficiency expected to be competitive to **existing chemical solutions.**

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SSI stationary machine will enable re-circulation of high-quality topsoil

Existing solutions for large-scale soil sterilization not well developed

Soil sterilization | Advanced process control | Handling various materials | Scalable solutions | Energy efficient

High efficiency -> Total Net Reduction in GHG/CO2 emissions

SSI is developing a complete on-site solution for soil sterilization:

- Simpler logistics
- Improved efficiency
- Multi-material handling
- Self-contained machine

SSI prototype evolution of stationary machine

Prototype 1. Demonstrating we can sterilize soil.

Prototype 2. Full scale prototype in test at Lindum, planned for commercial operation in 2023

Prototype 3. Efficient and scalable self-contained solution in test

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Why is spreading of weeds and seeds so difficult?

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Why stationary soil steamer?

- One third of fertile soil is lost
- 15 km² disappear in Norway every year
- 15 km² disappear every day in EU
- 5-10 mill tons fertile soil is degraded every year in Norway
- 50-100 mill tons in EU
- Vegvesenet and Bane NOR estimate hundreds of millions NOK in soil related problems in new projects

Third of Earth's soil is acutely degraded due to agriculture

Fertile soil is being lost at rate of 24bn tonnes a year through intensive farming as demand for food increases, says UN-backed study

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Stationary business model

- SSI cost for pasteurizing 1 m^3 soil is EUR 20
- The alternative cost to Bane NOR and Vegvesenet might reach 200 EUR per m^3
- Steamed soil is a higher quality product that should be sold at premium price

Veivesenet ber om godt vær: 30.000 lastebillass med jord skal flyttes for å gi plass til ny E18

NY JORD: Å flytte all dyrka mark som ligger der E18 skal bygges, blir en veldig stor jobb, påpeker prosjektleder Anne-Grethe Nordahl. Foto: Mette Kvitle

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Partners - academia

- NIBIO, Ås. Close cooperation about the effect of steaming on weeds and pathogens. Formal cooperation through RessursRetur, a project supported by Research Council of Norway (NO: Forskningsrådet) .
- NMBU, Ås. Close cooperation about steaming effects on soil microlife. Engagement of students in bachelor/master thesis.
- USN, Kongsberg. Students working on bachelor/master thesis.
- Norsk Landbruks Rådgivning (NRL). Cooperation with local departments for yield measurements.
- University of California, Davis. Joint experiments on strawberry steaming. Joint visits to customers.
- University of Arizona, Yuma. Joint experiments on steaming. Joint visits to customers, discussions about steam technology.

NIBIO
NORWEGIAN INSTITUTE OF BIOECONOMY RESEARCH

KARLSTAD UNIVERSITY

Norges miljø- og biovitenskapelige universitet

University of South-Eastern Norway

Norsk Landbruksrådgiving

UC DAVIS
UNIVERSITY OF CALIFORNIA

THE UNIVERSITY OF ARIZONA
Yuma Center of Excellence for Desert Agriculture

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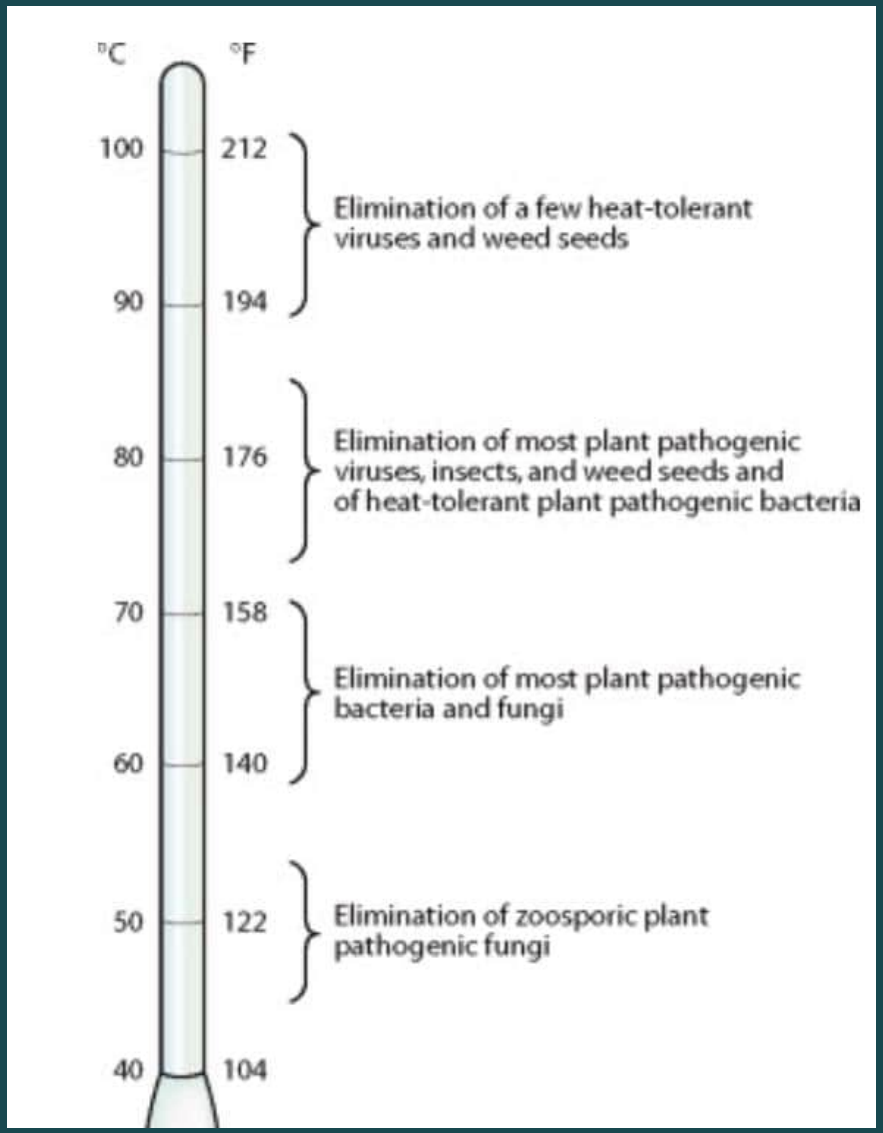
Experiments conducted by SSI with academia demonstrate superb steam efficiency against weeds and pathogens

Results are published and corresponds well with experiments conducted by scientist worldwide



Invasive Plant Science and Management

www.cambridge.org/inp

Research Article

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Stationary soil steaming to combat invasive plant species for soil relocation

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Abstract

Eradication of alien invasive species in the soil with steam as an alternative to chemical fumigation may allow contaminated soil to be reused. We have investigated steam disinfestation of soil to combat invasive plant species in three experiments including different temperatures and exposure durations using a prototype stationary soil-steaming device. The experiments included effects on seed germination of bigleaf lupine (*Lupinus polyphyllus* Lindl.), ornamental jewelweed (*Impatiens glandulifera* Royle), and wild oat (*Avena fatua* L.; one population from Poland and one from Norway), as well as effects on sprouting rhizome fragments of Canada goldenrod (*Solidago canadensis* L.) and Bohemian knotweed (*Reynoutria* x *bohemica* Chrtek & Chrtková). In Experiment 1, we tested four different soil temperatures of 64, 75, 79, and 98 C with an exposure duration of 90 s. In Experiments 2 and 3, we tested exposure durations of 30, 90, and 180 s and 90, 180, and 540 s, respectively, at 98 C. Seed pretreatment of 14 d cooling for *L. polyphyllus* and *I. glandulifera*, no seed pretreatment and 12-h moistening for *A. fatua* populations, and 5- and 10-cm cutting size for *R.* x *bohemica* were applied. Our results showed germination/sprouting was inhibited at 75 C for *I. glandulifera* (for 90 s) and 98 C for the other species; however, longer exposure duration was needed for *L. polyphyllus*. While 30 s at 98 C was enough to kill *A. fatua* seeds and *S. canadensis* and *R.* x *bohemica* rhizome fragments, 180-s exposure duration was needed to kill *L. polyphyllus* seeds. The results showed promising control levels of invasive plant propagules in contaminated soil by steaming, supporting the steam treatment method as a potential way of disinfecting soil to prevent dispersal of invasive species.

NIBIO

Norwegian University of Life Sciences

UCDAVIS UNIVERSITY OF CALIFORNIA

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Species tested in RessursRetur

Partners: Nibio, NMBU, Lindum, Vegvesenet,Toten Løpakkeri, Larvik Løk, Soil Steam International AS

The experiments included effects on seed germination of:

2020

Impatiens glandulifera	Himalayan balsam
Lupinus polyphyllus	Garden lupin
Avana fatua	Common wild oat
Reynoutria x bohemica/Fallopia x bohemica	Hybrid Japanese knotweed
Solidago canadensis	Canada goldenrod

2021

Heracleum mantegazzianum	Giant hogweed
Heracleum persicum	Persian hogweed
Impatiens glandulifera	Himalayan balsam
Reynoutria x bohemica/Fallopia x bohemica	Hybrid Japanese knotweed
Solidago canadensis	Canada goldenrod
Bromus sp.	Soft bromey
Echinochloa crus-galli	Cockspur grass
Solanum sp.	Nightshade-species

2022

Impatiens glandulifera	Himalayan balsam
Lupinus polyphyllus	Garden lupin
Avana fatua	Common wild oat
Solidago canadensis	Canada goldenrod
Heracleum mantegazzianum	Giant hogweed
Heracleum persicum	Persian hogweed
Echinochloa crus-galli	Cockspur grass
Rosa rugosa	Japanese rose/ Beach rose
Laburnum alpinum	Alpine laburnum
Laburnum anagyroides	Golden rain
Sambucus racemosa	Red elderberry
Solanum nigrum	Black nightshade

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Testing on several Invasive Alien Species

Testing on several Invasive Alien Species - results

Several different time vs temperatures has been tested

Conclusion:

No plant material or seeds from Invasive Alien Species survives combinations of 90 C+ steam in 3+ minutes

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Soilsteam S30 recircling soil which contains seeds and plant materials from Invasive Alien Species

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Moving forward

<u>2023</u>

- 4 machines in Norway
- Cooperating with universities in UK, SWE and USA

<u>2024</u>

- 15 machines totally and at least 1 in UK, SWE and USA
- Development new SoilSteam equipment for fighting Invasive Alien Species in “difficult areas” such as rivers, lakes, islands and forests

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