



The solution to soil degradation

September 2022

CLEAN SOIL. NO CHEMICALS.



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.



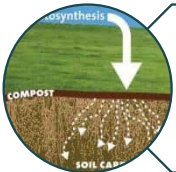
Resistant weeds and soil-born pathogens are hampering global food production. **59%** of farmers fields in US are now affected, increasing rapidly.



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.



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



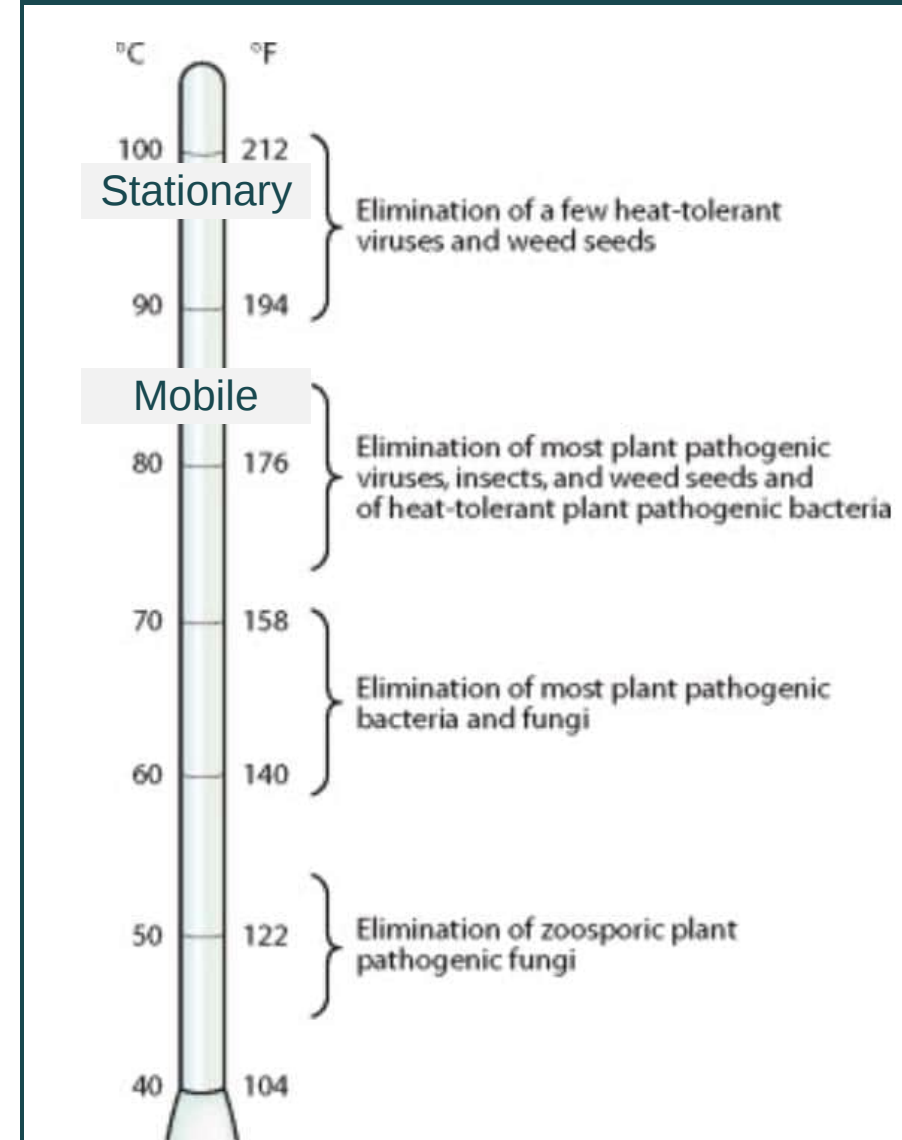
The amount of soil taken out of circulation due to invasive alien species or diseases increases

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

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



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 species
- Huge amount of soil transported to landfills.
- Strong political and economical incentives to find alternative solutions



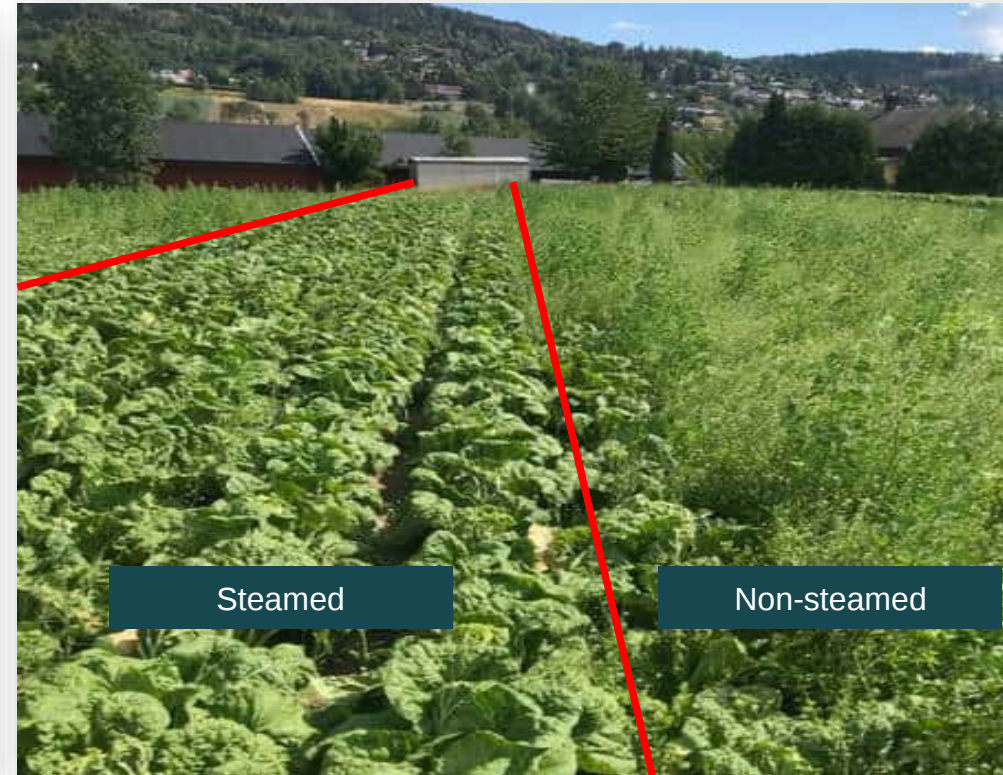
Steam removes weed, reduces harmful organisms, and increases yield

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 root 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.

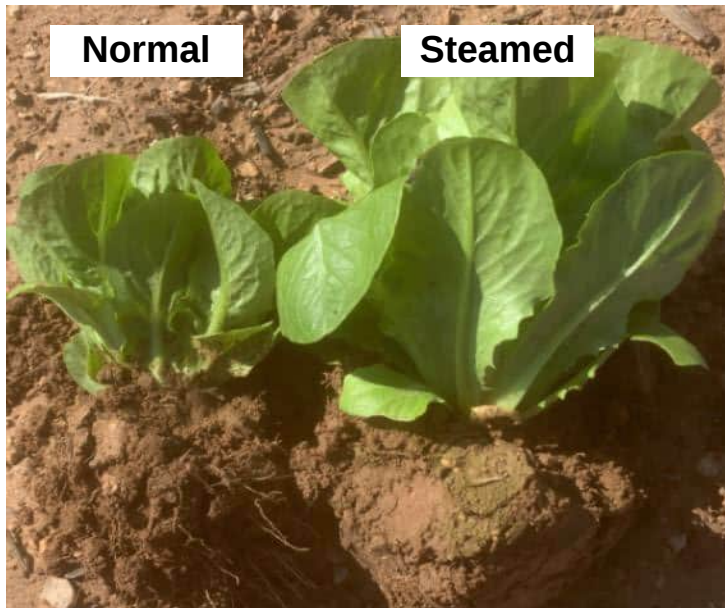
Picture from SSI tests in 2021.



Weed problems eliminated by steam in Chinese cabbage field.

Picture from SSI tests in 2019.

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*



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

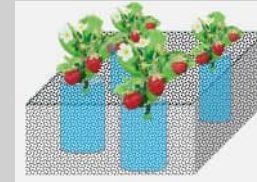
Multi-farm
usage

Semi-
autonomous
driving

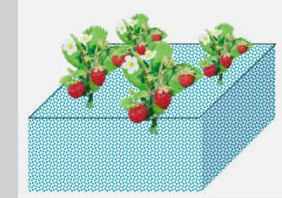
24/7
continuous
operation

With 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.**



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

Existing solutions for large-scale soil sterilization not well developed



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

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

Soil
sterilization

Advanced
process
control

Handling
various
materials

Scalable
solutions

Energy
efficient

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

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

Why is spreading of weeds and seeds so difficult?



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



Stationary business model

- SSI cost for pasteurizing 1 m³ soil is EUR 20
- The alternative cost to Bane NOR and Vegvesenet might reach 200 EUR per m³
- 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

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.



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/insp

Research Article

Cite this article: Bitarafan Z, Kaczmarek-Derda W, Brandsæter LO, and Fløistad IS (2021) Stationary soil steaming to combat invasive plant species for soil relocation. *Invasive Plant Sci. Manag* 14: 164–171. doi: 10.1017/insp.2021.25

Received: 12 June 2021
Revised: 19 August 2021
Accepted: 28 August 2021
First published online: 2 September 2021

Associate Editor:
Edith Allen, University of California, Riverside

Keywords:
Invasive species; resource management; thermal soil disinfection; weed management

Author for correspondence:
Zahra Bitarafan, Division of Biotechnology and Plant Health, Norwegian Institute of Bioeconomy Research, Høgskoleveien 7, 1433 Ås, Norway. (Email: zahra.bitarafan@nibio.no)

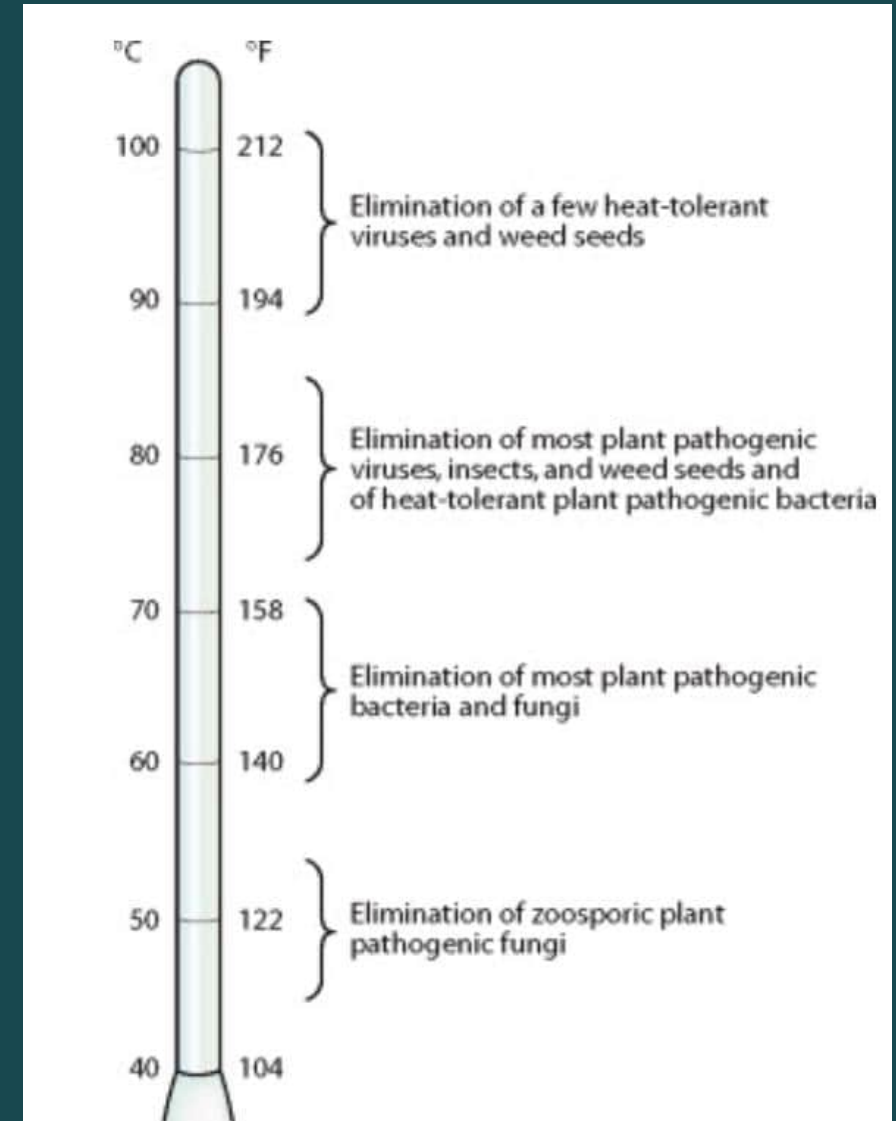
Stationary soil steaming to combat invasive plant species for soil relocation

Zahra Bitarafan¹, Wiktor Kaczmarek-Derda², Lars Olav Brandsæter¹ and Inger Sundheim Fløistad⁴

¹Postdoc, Division of Biotechnology and Plant Health, Norwegian Institute of Bioeconomy Research, Ås, Norway; ²Researcher, Division of Biotechnology and Plant Health, Norwegian Institute of Bioeconomy Research, Ås, Norway; ³Professor, Department of Plant Sciences, Faculty of Biosciences, Norwegian University of Life Sciences, Ås, Norway; ⁴Division of Biotechnology and Plant Health, Norwegian Institute of Bioeconomy Research, Ås, Norway and ⁵Researcher, Division of Forestry and Forest Resources, Norwegian Institute of Bioeconomy Research, Ås, Norway

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 disinfection 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 juncoweed (*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* Chrtk & 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.



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

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

2021

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

2022

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



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

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



Moving forward

2023

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

2024

- 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





SOIL STEAM
INTERNATIONAL

CLEAN SOIL. NO CHEMICALS.