CIVIC SERVICES

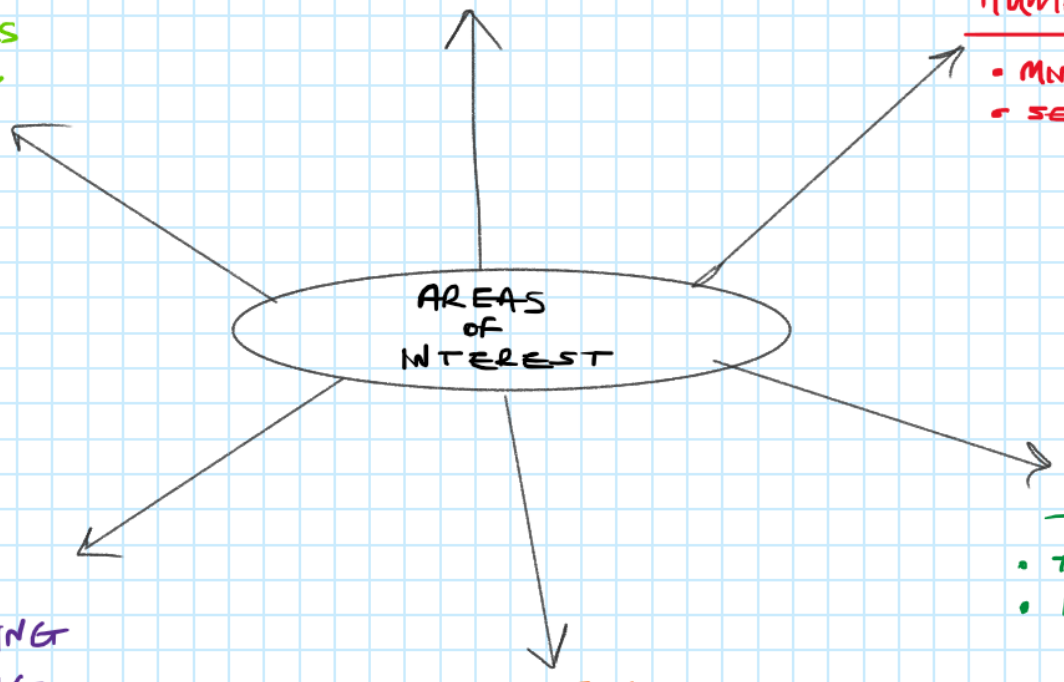
- POSTAL SERVICE / DELIVERY
- ROAD SWEEPING
- WASTE/RECYCLING COLLECTION
- FIREFIGHTING

PRIVATE SECTOR

- WAREHOUSE WORKERS
- PACKAGE DELIVERY
- SECURITY/GUARDS

HUMANITARIAN

- MINESWEEPING
- SEARCH + RESCUE
  - HAZARDOUS AREAS
  - EARTHQUAKES



MILITARY

- RECON/AREA MAPPING
- TARGET FOLLOWING
- RESUPPLY

ENVIRONMENTAL

- TREE PLANTING
- LITTER CLEANING/
  DECONTAMINATION
- LAND EROSION PREVENTION

AGRICULTURE

- FARMING
- CROP PLANTING/
  HARVESTING

Minesweepers:

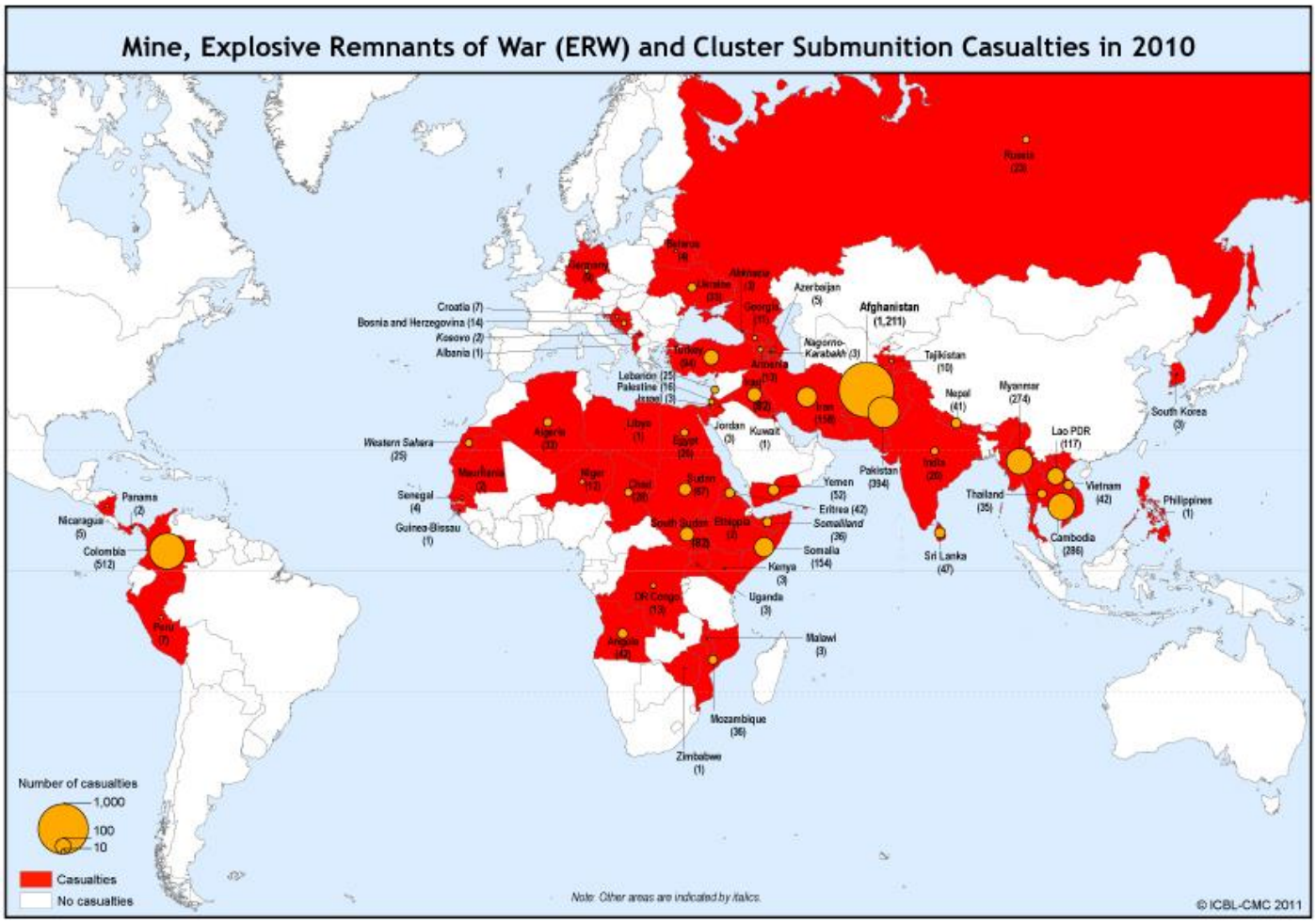


Figure 1 source: www.landminefree.org

- It is estimated that there are 110 million land mines in the ground right now. An equal amount is in stockpiles waiting to be planted or destroyed.
- Mines cost between $3 and $30, but the cost of removing them is $300 to $1000.
- The cost of removing all existing mines would be $50- to $100-billion.
- According to the 'International Campaign to Ban Landmines network', more than 4,200 people, of whom 42% are children, have been falling victim to landmines and ERWs annually in many of the countries affected by war or in post-conflict situations around the world.
- According to Landmine Monitor, number of landmine and UXO casualties was 11,700 in 2002 and 4286 in 2011.
- Mines kill or maim more than 5,000 people annually.
- Mine and explosive remnant of war casualties occur in every region of the world, causing an estimated 15,000 - 20,000 injuries each year.
- One deminer is killed and two injured for every 5000 successfully removed mines.
- Overall, about 85 per cent of reported land mine casualties are men, many of whom are soldiers. However, in some regions, 30 per cent of the victims are women.
- Mines create millions of refugees or internally displaced people
- The areas most affected by land mines include: Egypt (23 million, mostly in border regions); Angola (9-15 million); Iran (16 million); Afghanistan (about 10 million); Iraq (10 million); China (10 million); Cambodia (up to 10 million); Mozambique (about 2 million); Bosnia (2-3 million); Croatia (2 million); Somalia (up to 2 million in the North); Eritrea (1 million); and Sudan (1 million). Egypt, Angola, and Iran account for more than 85 per cent of the total number of mine-related casualties in the world each year.
- Until recently, about 100 000 mines were being removed, and about two million more were planted each year.
- If demining efforts remain about the same as they are now, and no new mines are laid, it will still take 1100 years to get rid of all the world's active land mines.
- For the military, mine detection rates of 80% are accepted since all the military needs are a quick breach in a minefield. For humanitarian mine clearing it is obvious that the system must have a detection rate approaching the perfection of 99.6%.

- The most common injury associated with land mines is loss of one or more limbs. In the United States, the rate of amputation is 1 for every 22 000 people. In Angola, it is 30 for every 10 000.
- In many of the most affected areas of the world, agriculture is the mainstay of the economy. Land mines are planted in fields, forests, around wells, water sources, and hydroelectric installations, making these unusable, or usable only at great risk. Both Afghanistan and Cambodia could double their agricultural production if land mines were eliminated.

Information sourced from: www.landminefree.org

This is a current area of autonomous robotic vehicle interest:

- **Coimbra University "Husky" minesweeper**

Figure 2 and information source: https://clearpathrobotics.com/coimbra-autonomous-demining-husky/

- Adaption of "Husky" unmanned ground vehicle from clearpath robotics (https://clearpathrobotics.com/husky-unmanned-ground-vehicle-robot/)
- outfitted with navigation and localization sensors, ground penetration radar and a custom 2DOF robotic arm with metal detector.
- A stereo vision system is used to perceive the rugged terrain
- depth imaging is accomplished by state-of-the-art point cloud perception algorithms.

https://youtu.be/xju4rgRL4j0

Package delivery:

Cleveron "self-driving robot courier" concept

Images from: https://www.cleveron.com/products/robot-courier

Soil Erosion Prevention:

Preventing Soil Erosion

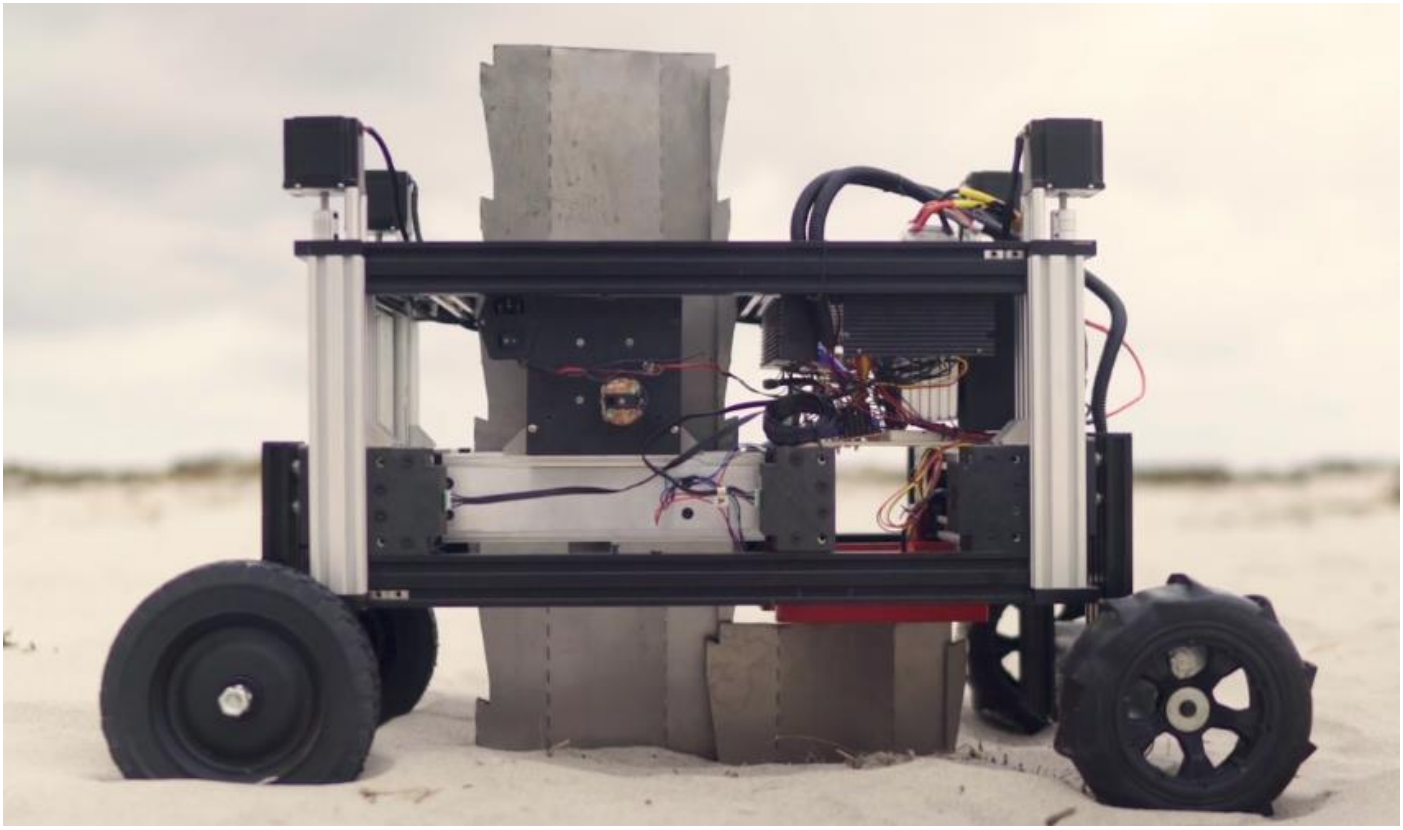
Harvard University: "Romu"

Dry land covers only one-third of the surface of our planet, but it's home to over 7 billion humans, the vast majority of the food we harvest, and an untold number of species of plants, animals, fungi, and bacteria. The amount of land available for all those organisms to share is getting smaller, however, due to factors such as increased soil erosion caused by intensifying storms and the agriculture, mining, and construction industries, and rising global sea levels that threaten to swallow beaches, estuaries, and coastal cities. Mitigating these large-scale environmental threats currently requires the time- and cost-intensive use of heavy machinery to build massive structures like dams and retaining walls, and is limited to areas that those machines can access.

Senior Research Scientist Justin Werfel, Ph.D. and Computer Science Fellow Nathan Melenbrink working within the Wyss Institute's Bioinspired Robotics Platform were experimenting with using a "swarm" of robots to install foundations for bridges and other large structures when they realized that their system – based on driving "sheet piles" (flat, thin, interlocking sheets of metal) into the ground – could also be applied to environmental restoration. Sheet piles can be used to form check dams, which are commonly used along shorefronts, riverbeds, and other vulnerable ecosystems to prevent erosion, reduce flash flooding, and promote groundwater recharge.

Inspired by insects like termites and ants that collectively build structures many times larger than themselves, the researchers created a sheet-pile-driving robot dubbed Romu. Romu drives sheet piles into the ground by leveraging its own weight and a vibrating hammer. By forcing each sheet pile into the ground in a multi-step process, adjusting its grip to a higher position on the pile each time, the robot can potentially install a pile taller than its own height.

"Many sensitive environments would be vulnerable to damage by the massive machines currently used to drive industrial piles," said Werfel. "Dividing the task among several smaller, more efficient robots that can work in parallel would allow us to more quickly and sustainably secure vulnerable habitats without the need for extensive supporting infrastructure."



Information and images sourced from: https://wyss.harvard.edu/news/saving-the-planet-with-robots-microbes-and-nanotechnology/