ANTS IN ARID REGIONS: ROLE PLAYERS IN ABOVE GROUND – BELOW GROUND ECOSYSTEM FUNCTION

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SOIL CONSULTATION: SITE HISTORY

- Determine history of area to be utilized prior to initiating any programmes
- Points to consider: human occupation record, crops, livestock, farming systems, natural vegetation, social economy and climatic patterns
• Soil health involves deterioration, stabilization, or improvement of soil ecosystem functions
• Pools of soil organic matter fluctuate with soil depth, reflecting stratification
• Temperature (soil warming / cooling), % water content, soil type and soil additions determining factors
  - Initiates soil functional shifts (organismal & chemical) over time
Concept interaction web, showing the major interactions between plants and associated insects (adapted from Brussaard, 1998).
ANTS & SOIL
Table 1. Ant richness* in different regions of the world

<table>
<thead>
<tr>
<th>Region</th>
<th>Number of species</th>
</tr>
</thead>
<tbody>
<tr>
<td>West Indies, Mexico, Central and South America</td>
<td>2233</td>
</tr>
<tr>
<td>North America, North of Mexico</td>
<td>585</td>
</tr>
<tr>
<td>USA</td>
<td>400</td>
</tr>
<tr>
<td>Europe</td>
<td>429</td>
</tr>
<tr>
<td>Africa (sub-saharan)</td>
<td>2500</td>
</tr>
<tr>
<td>Asia (parts of this region)</td>
<td>2080</td>
</tr>
<tr>
<td>New Guinea, New Britian and New Ireland</td>
<td>275</td>
</tr>
<tr>
<td>Australia</td>
<td>1100</td>
</tr>
<tr>
<td>New Zealand</td>
<td>23</td>
</tr>
<tr>
<td>Polynesia</td>
<td>42</td>
</tr>
</tbody>
</table>

`Ants are everywhere, but occasionally noticed. They run much of the terrestrial world as the premier soil turners, energy flow orchestrators, dominatrices of the insect fauna... One third of the entire animal biomass of the Amazonia terra firma rain forest is composed of ants ..., with each hectare of soil containing in excess of 8 million ants ...." (Hölldobler and Wilson, 1990).

‘... with a little help from my friends …’
ECOSYSTEM SERVICES / ECOLOGICAL FUNCTION OF ANTS IN SOILS

- Responsible for seed dispersal and **seed banking**
- Change layering through **bioturbation**
  - Pedogenesis
  - Soil texture profiling
- Act as **ecosystem engineers** and change physical structure
  - Niche construction
- Change **chemical content**
  - Decomposition
  - Organic matter transformation
- As **garbage collectors** ‘clean’ environment
- Serve as **bioindicators**
  - Environmental rehabilitation
  - Habitat change
  - Climate change
- As aggressive **competitors** affect community composition
- As **omnivores** responsible for **foodweb stochasticity**
- Major **energy flow** link in ecosystems
## ESTIMATED QUANTITIES OF SOIL (KG/HA/YEAR) BROUGHT TO THE SURFACE BY ANT AND TERMITE COLONY ACTIVITIES

<table>
<thead>
<tr>
<th>Ant &amp; termite species</th>
<th>Location</th>
<th>Turnover rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ant community</td>
<td><em>Atriplex</em> shrub steppe</td>
<td>350 - 420</td>
</tr>
<tr>
<td><em>Aphaenogaster barbigula</em> (Funnel ants)</td>
<td><em>Cailtris-Eucalyptus</em> open woodland</td>
<td>3360</td>
</tr>
<tr>
<td>Ant community</td>
<td>Heath (Western Australia)</td>
<td>310</td>
</tr>
<tr>
<td>Ant community</td>
<td>Wандoo woodland (Western Australia)</td>
<td>200</td>
</tr>
<tr>
<td>Ant communities</td>
<td>Chihuahuan Desert (CD) shrublands and grasslands</td>
<td>21.3 – 85.8</td>
</tr>
<tr>
<td><em>Macrotermes subhyalinus</em></td>
<td>Senegal</td>
<td>675 - 950</td>
</tr>
<tr>
<td><em>Heterotermes aureus</em></td>
<td>Sonoran Desert</td>
<td>750</td>
</tr>
<tr>
<td><em>Gnathamitermes tubiformans</em></td>
<td>CD – mixed grassland and shrubland</td>
<td>4095</td>
</tr>
<tr>
<td></td>
<td>CD – Creosote bush shrubland</td>
<td>801</td>
</tr>
<tr>
<td></td>
<td>CD – Black-grama grassland</td>
<td>981</td>
</tr>
<tr>
<td></td>
<td>Watershed</td>
<td>2600</td>
</tr>
</tbody>
</table>

*(Whitford, 2000)*
INFLUENCE OF ANTS ON THE PROPERTIES OF ANTHILL SOILS (TRENDS IN COMPARISON TO SURROUNDING SOILS)
In temperate regions ants transfer seeds to nests to feed on elaiosomes.

Seed bodies remain intact and germinate in these favourable endogeic seedbank microsites with more fertile soil environment and less competition.

Ants also major granivores in arid regions, storing and consuming seeds over time.

Across a scale of increasing aridity (e.g. Karoo) ants completely displace birds and rodents as granivores.

Seeds also accumulate on ant surface mounds outside nests to form exogeic seedbanks with germination rates 2x as high as in surrounding soil.
Examples of ant nest morphologies, with chambers and galleries. (from Hasiotis 2003)
• Soil and its biota are fundamental components of Earth's 'living skin' that most directly sustains life.
• Within that zone bioturbation (geologically-rapid soil displacement by soil-living biota) affects the Earth's soils.
• Bioturbation was Darwin’s ‘last idea’
• Relates to ecosystem engineering, biodiversity enhancement, ecosystem function and services, pedogenesis and soil profiling.
• Primary effects include soil production from saprolite, formation of surface mounds, soil burial, and downslope transport.
• Rates can be as rapid as sustained maxima of tectonic uplift.
• Alters fundamental properties of soil, including particle-size distribution, content of carbon and other nutrients and creep flux rate.
• In **hot, arid regions** ants replace **earthworms** as primary bioturbators.

• Ant bioturbation activities can increase **soil porosity** in mounds up to ca. 200 cm down soil profile.

• Ant bioturbation and foraging activities can affect soil properties **beyond perimeter of mound** and into the surrounding ecosystem.

• Plant **root biomass** and vertical growth pattern **follows vertical soil gradient of nests** as opposed to close- to-surface restriction in non-ant soils.

• Bioturbation activity generally **higher in sandy and silt soils** than in clays.

• However, ant bioturbation **homogenizes the soil texture profile**.

• Continuing ant bioturbation may **alter soil morphology** and even **soil classification**.
• Change physical structure of environment
  – **Above ground**: Ant mounds influence **aesthetic value** of an area
  – **Above ground**: Ant mounds provide additional **niches**
  – **Below ground**: Enhance **aeration** and **water infiltration**
• Ants **change nutrient standing stock** and **cycling rates** in soils by **transforming organic matter** and taking part in **litter decomposition** processes

• Generally **nest surface area** (NSA) increases until colony age 5–10 years and then levels off.

• NSA soil different from non-nest soil as follows:
  – N, P and NH₃ higher
  – pH lower
  – C and N mineralization higher

• **Soils in arid regions show weak total N storage**, but ants tend to change concentrations under plants over time

• **Organic matter** in ant nests contain **more nitrogen**, but mineralization is at a lower rate.
• Even though C pools in nests of certain ant species are insignificant at the ecosystem level, their C content was found to be 3-12 times higher than surrounding environment on an area basis (g m⁻²).

• C is carried into nests as honeydew, prey, resin, and plant litter and supplementary C is added to nests from aboveground litter fall and fine root growth.
• Downside:
  – Common general perception exists that litter-carrying ant activities increase soil nutrient levels and availability.
  – However, their territories are often characterised by reduced levels of leaf litter and, consequently, soil nutrients.
  – This nutrient depletion factor must be taken into account when considering potential impacts of ant nests for plant regeneration.
GARBAGE COLLECTORS

- Ants omnivorous, but also opportunistic feeders
- Environmental waste and garbage = ant food
- Removing waste rids environment of potential sources for disease incubation and environmental contamination
BIOINDICATION

• Land use practices change ant richness and abundance, BUT they show **tolerance** or **resilience** and can **reinvade**

• This labels ants as primary bioindicators of environmental condition:
  - Due to subterranean life-style (ca. only 10% of nest outside at any time) > resistant to pollution > thus good soil indicators of **mine-site soil rehabilitation**
  - In crop fields species assemblages correlate with soil variables (*i.e.* cultivated fields vs field margins), tillage practices (*i.e.* conventional vs conservation) and insecticide use > broad spectrum bioindicators of **agroecosystem condition**
  - Bioindicators of pulsed cattle grazing impact > early warning system for **grazing pressure**, *i.e.* overgrazing and soil compaction
BIOINDICATION OF CLIMATE CHANGE

- Ants becoming simplistic, but reliable indicators of climate change
  - Physically large species vs physically small species
  - As habitat complexity (vegetation) decreases large ants displace small ants
  - Large ants > eyes on top of head for wider view, more competitive, fast moving and agile > suited for open habitats
  - Small ants > eyes on side of head, docile behaviour, slow moving > suited for dense habitats
LINKING PLANT AND ANT TRAITS TO UNDERSTAND COMMUNITY STRUCTURE IN ARID REGIONS

- Functional approach > trophic/multitrophic system > combine plant and ant traits to environmental condition
- Components related (environment, vegetation & ants) using correlation stats > uncover causal structure between components
- Results > vegetation direct effect on ant community composition > environment only indirect effect on ant community composition through vegetation structure *
- Aridity most significant link with ant functional traits
- New approach useful in identifying mechanistic explanations of multitrophic community assembly and predicting their evolution under changing environmental conditions
- Possibly also of practical value in conservation biology for assessing habitat quality

(modified from Frenette-Dussault et al., 2013)
SOIL ANALYSIS: AN INTEGRATIVE APPROACH

- Biological
- Soil health
- Physical
- Chemical