Researching links between sustainable and healthy organic systems

Niels Halberg
International Centre for Research in Organic Food Systems
Sustainable agriculture – the way forward

Sustainability in agriculture means achieving higher yields from less land with less water and energy...

...while ensuring the profitability of farming,...

...caring for the environment...

...and meeting the expectations of society.

We make progress in sustainability through innovations at all levels!
No surprise: cost of organic is higher

Surprise: conventional apple has a slightly better ecological profile

Organic causes less waste water and consumers less energy form fertilizer and pesticide production

But overall energy consumption, CO2 emission and land use is higher

The drivers are
  ➔ Higher use of machinery (+70%)
  ➔ Lower yield (-30%)

Sustainability can be quantified by a comprehensive eco-efficiency analysis
FAO/OECD Expert Meeting: IMPROVING FOOD SYSTEMS FOR SUSTAINABLE DIETS IN A GREEN ECONOMY. -September 2011

• FAO defines sustainable diets as
  – “those diets with low environmental impacts
  – that contribute to food and nutrition security and to healthy lives
  – for present and future generations.

• Sustainable diets are
  • protective and respectful of biodiversity and ecosystems,
  • culturally acceptable, accessible, economically fair and affordable,
  • nutritionally adequate, safe and healthy,
  • while optimizing natural and human resources” (FAO, 2010c).
Sustainability as maintaining and enhancing critical capital

Sustainable development: Welfare does not decline over time = managing and enhancing a portfolio of assets

- Natural capital, $K_n$
- Physical capital, $K_p$
- Human capital, $K_h$

Can $K_p$ and $K_n$ substitute for erosion of $K_n$?

Weak $S$: Yes, All $K_n$ are non-essential
Strong $S$: No, Some $K_n$ are essential

- What is the critical capital for ecosystem services?
- Which capital assets can resp. cannot be substituted by other types of capital?

Barbier & Marcandia, 2013: A new Blueprint for a Green Economy
The classical 3 dominant visions of agricultural sustainability

• Food sufficiency
  – Agriculture as instrument for feeding people

• Stewardship
  – Ecological balance and bio physical limits

• Community
  – Agrees with stewardship but also focus on:
    – Vital, coherent rural cultures

G. Douglass, 1984
The meaning of sustainability: 
*Assessment with a long term perspective*

**Thompson, 1995, after Douglass, 1984**

- **Resource sufficiency** *(food sufficiency):*
  - Efficient food production
  - Foreseeable use of resources,
  - Fulfilment of present and future needs: Capacity to produce
  - Substitutability among resources
  - Nature is robust – a resource for humans

- **Functional integrity** *(Stewardship & Community):*
  - Availability and regeneration of critical renewable resource base
  - Resilience and avoidance of irreversible changes of complex agro-ecological and social systems
  - Build institutions to support moral obligations
  - Nature is "vulnerable" – we are an integrated part
  - Systemic approach, link to health

What may Organic Farming offer in relation to goals for sustainability?
Which crucial ES and capital types do OA help maintain?

Ecosystem services
### The four basic principles of organic agriculture

Endorsed by IFOAM, September 2005

<table>
<thead>
<tr>
<th>Health</th>
<th>Ecology</th>
<th>Fairness</th>
<th>Care</th>
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<tbody>
<tr>
<td>Agriculture sustain and enhance health of soil, plant, animal</td>
<td>Agriculture based on living ecological systems and cycles related to common environment and life opportunities</td>
<td><strong>Relationship</strong> and responsible management in light of future generations and environment</td>
<td><strong>Technology assessment, and risk aversion, acknowledge of limited understanding of ecosystems, respect for practical experience and indigenous knowledge</strong></td>
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<table>
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<tr>
<th>Keywords and concepts</th>
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<td>Immunity, resilience, regeneration</td>
<td>Recyling, efficient resource use, ecological balance, genetic and agricultural diversity, habitats</td>
<td>Ecologically just use of natural resources and environment</td>
<td><strong>Technology assessment, and risk aversion, acknowledge of limited understanding of ecosystems, respect for practical experience and indigenous knowledge</strong></td>
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<td>Healthy soil</td>
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<td><strong>Technology assessment, and risk aversion, acknowledge of limited understanding of ecosystems, respect for practical experience and indigenous knowledge</strong></td>
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<td>Healthy livestock (Healthy people?)</td>
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**Which “sustainability concept” apply to each principle?**
OA is good for biodiversity and biodiversity is good for OA (...?!) 

Organic farmers use more **Agro-ecological methods:**
- Mixed crop rotations, intercropping, …
- Grasslands and green manure,
- Habitats and non-farmed areas
- Non-chemical pest management

Promoting *functional diversity* means enhancing and benefitting from *Ecological service functions*:
- Pollination
- Pest and disease prevention
- Biodiversity preservation,
- Soil quality
- Resilience
- In situ conservation of genes
Growing carrots in rows between grass-legume mixtures for enhanced pest control and nutrient recycling in Danish horticulture crop rotation experiment "Vegqure", [www.vegqure.elr.dk/uk](http://www.vegqure.elr.dk/uk) (Source: ICROFS)
Soil degradation and food security

- Soil degradation
  - Erosion
  - Compaction
  - Crusting and salinization
  - Nutrient mining
  - Loss of soil organic matter

- Food security
  - Yield reduction
  - Efficiency of input use reduced
  - Micro nutrient deficiency

Need for paradigm shift in land husbandry and Principles and practices for soil management

R. Lal, Food Security journal, 2009
Solutions for soil and food quality improvements

- Improve soil structure and quality
- Adoption of diversified cropping systems,
- Agro-forestry and mixed farming
- No-till agriculture
- On-farm experimentation and adaptation
- Adoption of diversified cropping systems, indigenous foods, GMO’s high in nutrients
- Mulching and recycling organic residues
- Inoculating soils for improved Biological Nitrogen Fixation
- Microbial processes to increase P-uptake
- Water conservation and water use efficiency

R. Lal, 2009; Okalebo et al., 2006

With adoption of proven management options, global soil resources are adequate to meet food and nutritional needs of the present and future population
Organic Agriculture and soil quality

Results from different long term experiments:

• The organically treated soils were
  – physically more stable,
  – contained smaller amounts of soluble nutrients and
  – biologically more active than conventional
    \textit{(DOK trials, Mäder et al., 2002)}

• Under organic farming the soil organic matter
  – captures and retains more water in the crop root zone

• Water capture in organic fields can be 100% higher than in conventional fields during torrential rains \textit{(Rodale Institute, 2008)}

Soils as “regulating ecosystem services”
Carbon sequestration in long term experiments

<table>
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<tr>
<th>Field trial</th>
<th>Components compared</th>
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<td>Running 1994 to 2002</td>
<td><strong>Rodale</strong> FST, USA,</td>
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<td>(Hepperly, et al., 2006;</td>
<td>Organic, FYM</td>
<td>1,218</td>
<td>97 %</td>
</tr>
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<td>Pimentel, et al., 2005)</td>
<td>Organic, legume based</td>
<td>857</td>
<td>92 %</td>
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<td>Running since 1981</td>
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<td>217</td>
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<td><strong>Frick</strong> Reduced Tillage</td>
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Niggli et al., 2009, FAO brochure
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Average difference between the best organic and the conventional treatments: 590 kg carbon (2.2 t CO\(_2\)) per hectare and year.

Niggli et al., 2009, FAO brochure
Do we simplify ES too much?

Richard B. Norgaard (Ecol. Econ. 2010):

*Ecosystem services:*

*From Eye-opening metaphor to complexity blinder*

- Stock and flow models, remuneration of simple ES Vs.
- Accepting complexity, limitations to understanding of ecosystems

Is there a specific role for organic agriculture in the second approach? Or, is the focus on functional biodiversity in OA part of first approach?
Challenges for organic farming in light of the globalisation process

- Global procurement systems and increased supermarket sales
- Long distance transport (food miles, energy use),
- Harmonisation and supply-on-demand favours
  - Large-scale production and trade
  - Specialisation
- Increased global competition means
  - Pressure on organic principles and
  - Commodification of common goods
- Transparency, trust, nearness…?
- Local ownership and control of certification
- Local embedment of organic principles
- Fair trade, partition of price premium

(Hall & Mogyorody, 2001; Woodward et al., 2002; Rundgren, 2003; Schwartz, 2002; Milestad & Darnhofer, 2003; Raynolds, 2004; Alrøe et al, 2006)
ORGANIC MOVEMENT LAUNCHES A NEW SUSTAINABILITY INITIATIVE:

THE SUSTAINABLE ORGANIC AGRICULTURE ACTION NETWORK (SOAAN)

The Sustainable Organic Agriculture Action Network (SOAAN) exists to develop activities that positions organic agriculture and its related supply chains as a holistic, sustainable approach to agricultural production for all of human society. Working together as an alliance of
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<td>Practice based indicators (examples)</td>
<td>Soil fertility building; Diversification of crop rotation and intercropping Functional diversity Avoid soil compaction Livestock health management</td>
<td><strong>Resource sufficiency</strong> Functional integrity</td>
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<td></td>
<td><strong>N cycling on farm</strong> Production and use of renewable energy Reduction of GHG emissions Use of traditional breeds and diverse varieties.</td>
<td>Good working conditions Recruitment Animal housing and access to outdoor areas.</td>
<td>Participatory innovation and technology risk assessment (biotechno-logies, molecular -omics and nano-technologies)</td>
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<td>Maintenance of biotopes and permanent grassland</td>
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<tr>
<td>Results based indicators</td>
<td>Animal health and welfare indicators</td>
<td>% imported manure, ( N_{\text{surplus}, \text{kg ha}^{-1}} )</td>
<td>(see ecology)</td>
<td>New technologies implemented based on careful risk and benefit assessments</td>
</tr>
<tr>
<td>(examples)</td>
<td>Soil quality indicators</td>
<td>Energy use (( MJ \text{ kg product}^{-1} ))</td>
<td>Global warming impact ( (g \text{ CO}_2\text{-eq kg product}^{-1}) )</td>
<td>Technologies avoided from a risk aversion principle</td>
</tr>
<tr>
<td></td>
<td>- changes in soil organic matter</td>
<td>% renewable energy use</td>
<td>Ammonia emission</td>
<td></td>
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<td></td>
<td>biological soil indicators</td>
<td>P Surplus, ( \text{kg ha}^{-1} )</td>
<td>Accidents to farm workers years(^{-1} )</td>
<td></td>
</tr>
<tr>
<td></td>
<td>% area treated with pesticides (Cu, pyretrum etc.)</td>
<td>% non-cultivated habitats of total farm area.</td>
<td>Social conditions</td>
<td></td>
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Indicators should:

- Describe relevant aspects of a food or farming systems,
- Be meaningful to the farmer and to other parties,
- Be scientifically valid and reproducible,
- Be possible to register and calculate by farmers or local advisors at reasonable costs,
- Be sensitive to changed management practice and be able to show changes over time,
- Be predictable and suitable for strategic (multi-objective) decision making.
## Types of Agri-environmental indicators
- linking farmer practices to environmental impacts

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<tbody>
<tr>
<td>1.</td>
<td>Farmers practise</td>
</tr>
<tr>
<td>2.</td>
<td>Resource &amp; Input use</td>
</tr>
<tr>
<td>3.</td>
<td>Input-output account</td>
</tr>
<tr>
<td>4.</td>
<td>Emission estimates</td>
</tr>
<tr>
<td>5.</td>
<td>Environmental Impact, (aggregation over food chain in categories)</td>
</tr>
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<tr>
<td>1.</td>
<td>Fertiliser plan made?, harvest interval respected?</td>
</tr>
<tr>
<td>2.</td>
<td>Amounts of Feed, Fertiliser, Energy, Pesticides,</td>
</tr>
<tr>
<td>3.</td>
<td>Nutrient surplus per ha, Fossil energy per kg, Feed efficiency</td>
</tr>
<tr>
<td>4.</td>
<td>Nitrate loss, Exo-tox (pesticides)</td>
</tr>
<tr>
<td>5.</td>
<td>Acidification, Global Warming Potential, per kg product</td>
</tr>
</tbody>
</table>
Reference values for benchmarking:

Farmgate P surplus by farm type and manure P supply

Stocking rate, livestock units per ha, after net manure sale

1 LU=36 pigs 30-102 kg

Avg. Fattening pigs

Variation in CF of milk between farms

Kristensen et al, 2011
Variation in CF of milk explained by different management factors

- Herd efficiency: 27%
- Farming intensity: 17%
- N yield crop: 7%
- Grassland: 5%
- Combined milk and meat: 4%
- Not accounted for: 40%

*Kristensen et al, 2011*
Areabased indicators vs. Product oriented
Comparison of pig production systems

Per ha land use

Eutrophication
Pesticide use
Energy use
kg of pig
Terrestrial Toxicity

GAP
RL
OA

Per kg pig

Eutrophication
Pesticide use
Energy use
Land use
Terrestrial Toxicity
Acidification
Climate change

(Basset-Mens and van der Werf, in press)
An overall objective: *Eco-functional intensification*

Intensification of land use and agriculture by means of

- *improved knowledge and application of biological principles and agro-ecological methods*

- *increased cooperation and synergy between different components of agro-eco systems and food systems,*

with the aim of enhancing the health and productivity, adaptability and resilience of all its components.
Icrofs research and development strategy 2012: Primary themes

- Growth
- Credibility
- Resilient systems
Focus area 4: Microbial interactions in soil, plants, animals, fodder and food

Little knowledge!

Decisive role!

Microbes, soil, plants, animals, fodder and food
BioConval – Conversion of manure to high value poultry feed in large scale egg production systems

Steen Nordentoft
Challenges in the organic egg production

• **Composition of the feed**
  – Balanced feed containing all necessary nutrients and being organic

• **Animal welfare**
  – Cannibalism
  – Lower production, if undersupplied in essential nutrients

• **Improved utilization of the manure**
  – Conversion of nitrogen to high value protein
  – Improved value of the compost
  – Fresh insects are a part of organic hens diet
  – However, are larva grown on manure safe to use as fresh feed?

Steen Nordentoft
, DTU/FOOD
Degradation of *Salmonella* Enteritidis in poultry manure

- **S. Enteritidis in manure** no larvae
- **S. Enteritidis in manure** with larvae
- **S. Enteritidis inside the larvae**

(CFU / g manure)
Focus area 6: Animal and human health

Prevention

Health promoting qualities
Introduction

Farm specific strategies to reduce environmental impact by improving health, welfare and nutrition of organic pigs

C. Leeb
Amsterdam, 15th May, 2013
2nd CORE Organic II research seminar
Three Systems

75 farms in 8 countries

To identify
- animal - environment interactions in three systems

Hypothesis
- all systems are able to ensure good welfare and low environmental impact
- when well managed

Indoor with concrete outside run

Partly outdoors

Outdoors

ProPIG Amsterdam, 15.5.2013 Coreorganic2 Research Seminar
Farm specific strategies for improvement

To develop and implement

- **Farm specific strategies** to:
  - reduce environmental impacts
  - by improving health, welfare, nutrition and management of organic pigs

- To **disseminate knowledge** to national advisory bodies and farmers

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**ProPIG Amsterdam, 15.5.2013 Coreorganic2 Research Seminar**
Sustainable intensification

A productive agriculture that conserves and enhances natural resources.

- uses an ecosystem approach that draws on nature's contribution to crop growth
  - soil organic matter, water flow regulation, pollination and natural predation of pest
  - and applies appropriate external inputs at the right time, in the right amount

CPI represents a major shift from the homogeneous model of crop production to knowledge-intensive, often location-specific, farming systems.

Is there a paradigm shift undergoing?

FAO, 2011
Focus Area 2: New organic production systems

New integrated systems

Intensification

Integration
Field studies of root growth

Wheat plots in the field with 3 m long rhizotrons for root observation installed.

Drilling equipment for insertion of 3 m long minirhizotrons

Insertion of a minirhizotron

Kristian Thorup-Kristensen, KU
Exploiting biodiversity:
- new species as cover crops

Kristian Thorup-Kristensen, KU
Root exploitation dynamics of rotation

- Convention mixed rotation: 22% exploit.
- Organic rotation including cover crops: 38% exploit.

Kristian Thorup-Kristensen, KU
Core theme 2: Environmentally sustainable growth and intensification of agriculture

Core theme 3: Assessing and reducing trade-offs between food supply, biodiversity and ecosystem services