Wednesday, April 16, 2014

AGR 2050 Notes

Agroecology

What do you consider as the top environmental issues facing agriculture?
- nutrient management - cost of production, waste, runoff
- deforestation - ruining biodiversity which ruin species that perform “environmental services”
- chemical use - increasing weed resistance
- sustainability - decreasing organic matter in soils, quality lowers, erosion

Top Ten Environmental Problems
1. Apathy - people do not like to change
2. Human population growth
3. Habitat loss, fragmentation & degradation - fresh water
4. Fresh water quality and quantity
5. Threat of disease - plant and animal
6. Unsustainable agricultural production
7. Air pollution
8. Degradation of marine habitats
9. Global climate change
10. Invasive plants and animals

Main questions: How do we protect the food supply/environment?

Biodiversity - important to not lose keystone species

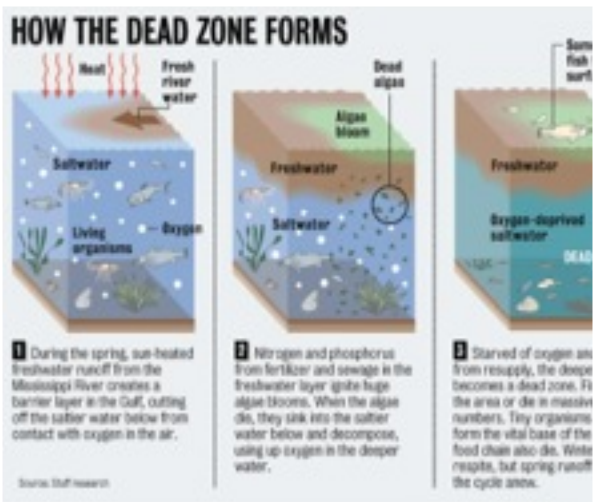
Keystone species: performs a specific key functions in the environment
extinction becomes more critical

The greater the diversity = the greater the stability

Invasive species - kills species that live there because they are so aggressive (forms a similar style of mono cropping)

World Population Forecast
- Current population = 7 B
- 7.5 to 8.3 B by 2050
- World population by 2100 = 10.1 B
- K = 12 B

Water Quality and Quantity
- a corn crop that produces 9 tonnes per hectare requires approximately 6 million litres of water during the growing season
- Ogallala Aquifer
- Dead zone Gulf of Mexico = 11,000km^2



Systems thinking “the ripple effect”
- Systems thinking is fundamentally different from that of traditional forms of analyses
- Traditional analyses focuses on separating the individual pieces of what is being studied
- Reductionist science - to break into constituent parts
- Systems thinking ...

Systems thinking works best for:
- complex problems that involve many sectors
- Recurring problems where past attempts have made the situation worse
- Issues where an action effects the environment e.g. nitrogen use
- Problems where the solution is not obvious
- Modern agriculture is rooted in maximizing productivity, economic return and efficiency
- Agricultural production is also part of a larger ecosystem that operates according to its own set of rules
- Agriculture is ecological management

Ecosystem Analyses - a system analyses approach

- <u>Question of scale:</u> farm, landscape, water shed, biosphere
- An ecosystem has no particular size
- Consists of all living organisms (biotic factors) within a defined area as well as the physical environment (abiotic factors) linked together as a functioning unit
- An ecosystem is a community of living organisms and non living physical and chemical components of the environment such as soil, light, moisture, and temperature that work together

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Agroecosystem

- The agroecosystem can be viewed as a subset of the conventional ecosystem. Agroecosystem deals with the human activity of agriculture including social, economic and environmental impact
- For example, agriculture has an impact on animal and plant species, energy flows as well as net nutrient balance

This course will address the concept of agroecology from a perspective of intensive agricultural production.

Evolution of Agroecosystems

Agroecosystem is constantly changing because of climate, demand and what is available.

First agroecosystem started at the end of the Ice Age with the domestication of maize.

Why this sudden change?
- Social vs environmental changes

-Change in climate
-Demographic: population pressure
-less work, more productive
-more stable yields, broader diets

- a millenium or more

- Depending on the wild species characteristics
- Different eco-zones

Agriculture originated in different places of the world at about the same time.
They are all nearing the equator.

Wet vs Dry season caused major challenges and major changes in crop morphology, physiology and nutrient and water requirement.
Had to take a 1 year growing cycle to a 6 month growing cycle along with drying and storing the seeds for the next season.

Domestication syndrome
• Crops acquired a new set of characters
- bigger fruits and seeds
- loss of seed dispersion
- dormancy
- tillering
- reduction in toxic compounds
- size
• Recurring pattern in various crops

Early agroecosystems
(Middle oft he first millenium BC)
• Slash and burn, land clearing around settlements. Plow in some areas.
• Damned and irrigation as soon as ~4000 BC
• there were already marked differences in the type of agriculture found in the world
- “seed” agriculture
- Tropical vegeculture
- Wet-rice cultivation
• Major river deltas (Fertile crescent)
e.g. Nile River Delta

Dry land farming
Livestock - manure, grazing on stubble
Fallow

Tools
Plow, harrows, sickles, drills
(wood - later from stones)

Easier to move East West than North South. Why?
Changes were dictated by the climate, terrain changes, and photoperiod.
(crops needed similar growing conditions from which it started with)

In North America
it started with companion planting (1300 AD)

The three sisters
maize steady, squash down, beans up
Why?
squash prevents weeds
beans have a way to grow up (on maize)
nitrogen fixation
complete human nutrition
squash leaves prevent pests (fuzzy)

Rocky mountain bee plant was sometimes added.

Together the three sisters produce more food, mutual benefits than a similar area planted to any one of these three crops in isolation.

Benefit
hillsides,
prevent run off
retains water
stones around help maintain heat

Still used today for rice terraces in Banaue and the Philippines

Europe
the longest lasting agroecosystems in history
• Introduced into Britain in the 7th century and persisting until the 14th century
• Introduction of the heavier plough and the "three field system" in the middle age
- Sequence of winter wheat or rye, spring sown oats, barley
- beans or other legumes, grazing
- ploughed fallow
• Low productivity

Brief Excursion Into Agroecosystems Revolutions
• Revolution 1: Domestication

In the last century agriculture has changed more than in the last 10000 years.

Agricultural revolution of the 19-20th century
• Intensification of farming, after WWII
• Enormous increase in productivity
1900-1914: 81 minutes to produce a bushel of corn, now it takes 2 min

Incidence of the industrial revolution on farming

- Industrial revolution (steam engine 1776, mechanization 100 years later)
- New technologies: Haber-Bosh process for N fertilizers
- Paradigm changed - Aes were not limited by environmental characteristics anymore
- Role of science - BREEDING

Norman Borlaug (1914-2009)

- "The Man Who Saved A Billion Lives"
- Nobel peace prize in 1970 in recognition of his contributions to world peace through increasing food supply

The Green Revolution - 1940 to late 70s
high yielding varieties (wheat - rice)
-new plant ideotypes-hybrids
-response to fertilizer, stress tolerance
-photoperido insensitivity,
-short growth duration
What changes in Aes?

- Second round of intensification
- Increase in *per capita* food production on almost similar surface area
    - Efficient management practices x high yielding varieties x fertilizers use x efficiencies of scale
    - =dramatic increase in yields

Negative agroecological impact?
monoculture - loss of diversity
pesticide resistance

Agroecological post GR problems
Sustaining stable food production

- Wide scale monocropping and decrease in Aes diversity

- number of variety grown, number of crops, shorter rotations

- Increasing incidence of pest, disease and weed problems
- Increase use of inputs, less legume cover crops
- Deteriorating soil structure and fertility
- Decrease in sustainability and resilience to stresses
- Mitigated or no success in more marginal agricultural areas

- This partly accounts for the relative lack of impact of the Green Evolution in Africa

How much more can we squeeze out of our current Aes?
World population vs Productive land

Coming up? Green Revolution 2.0

Aes will have to become more productive, especially in Asia and Africa

Which way forward?
Do more... with less on the same amount of land
- Improving yield potential and decreasing yield gap +60%!!
- Better adapted varieties - crop substitution
- Agronomical solution and breeding for low input agriculture
- Enhance resilience of cropping systems to stress, yield and stability
- Improving input use efficiencies: Biotech?
- Blue sky research: change plant biology (C4, legumes)

Urban Agriculture and Sustainable Cities

Urban agriculture is experiencing a resurgence not seen since the Victory Gardens. (WWII)

Problems associated with urbanization
10 million or more: To feed a city of this size at least 6,000 T of food must fed every day

Low income urban dwellers spend between 40% and 60% of their income on food each year

In 2007, for the first time in human history, the world population became more urban than rural
- About half of the world's population lives in cities: 3 billion, compared to 1.5 billion 30 years ago
- Between now and 2030 nearly all population growth will be in urban areas of developing nations
- Some cities are growing two or three times faster than the country's overall population

Most of the world's fastest growing cities are found in low-income countries of Asia and Africa with young populations

- That is equivalent to almost five new cities the size of Beijing, each year
- the current number of urban dwellers in Sub-Saharan Africa is expected to grow by almost 45%
- Urbanization in low income countries is accompanied by high levels of poverty, unemployment and food

Book "The Real Population Bomb"

- In many developing countries, urban growth is being dried not by economic opportunity but by high birth rates and a mass influx of rural people seeking to escape hunger, poverty and insecurity
- Centuries vs Generations
- Nightmare for governance/environment: sprawling, degraded and impoverished cities with large, vulnerable populations

Urban Agriculture
- Urban agriculture is located within or on the fringe of a town, a city or a metropolis
- Grows or raises, processes and distributes a diversity of food and non-food products
- (re) uses largely human and material resources, products and services found in and around that urban area

Can we solve some issues associates with urbanization by developing urban agriculture?
- Food security and nutrition
- Livelihood
- Buffer for food price fluctuations
- Waste/Environmental Management

Advantages
- Huge growing market for agricultural products (especially for livestock products, high value horticultural crops)
- Producers and processors located close to cities have comparative advantages to supply these markets (perishability etc)

Real Life Opinion
- Save money, they harvest enough vegetables to sell in the street
- The couple say contrary to what most people think, farming is not time consuming or tedious
- The seeds they plant only take a few weeks to blossom into onions, cabbage, eggplant and spinach
- If you do not have a job, you need to farm.

Farming to improve the urban environment.
- Use of contaminated urban land for food
- Microclimate improvement
- Conservation of urban soils
- Waste and nutrient recycling / Water management
- Biodiversity
- Global warming and atmospheric pollution
- Environmental awareness, quality of life
- Reduces the need to transport produce into cities

- Greenbelts also stabilize environmentally fragile land, such as hillsides and river banks, and protect them from being used

Risks?
- Wastes also contain contaminants and pathogens
- {ppr management and misuses of agro-chemicals, animal diseases, high density production and marketing
- Traffic density and agriculture on contaminated roadside soils, air and water (leafy vegetables vs tubers)
- The geographical closeness of production areas with population centers and the short marketing chain increases health risks
- Urban agriculturist are often not "farmers" - little knowledge
- Lots of innovation is required
- Not that simple: Alliances are needed

Production Systems
Intra-urban agriculture: takes place within the inner city
Most cities and towns have vacant and under-utilized areas

Peri-urban agriculture: takes place in the urban periphery

What can you produce in a city?
Horticulture
- high demand throughout the year
- profitable
- lower economy of scale
- greater labour demand compare to field crop

Livestock
- meat demand is increasing in developing cities
- dairy products
- poultry and eggs
(note not in Canada)

Cultivation on rooftops
- Long history reaching back to Scandinavian settlements since the Middle Ages or earlier
- World's largest rooftop soil farms, located on two roofs in New York City grow over 40,000lbs of organically-cultivated produce per year

Other services for rooftops
- effective in reducing urban flooding
- capture carbon
- help manage urban heat islands
- habitat for urban wildlife

Not just “gardening”

Soils in the city: concrete jungle
- 1992: defined urban soil as “... soil material having a non agricultural manmade surface layer more than 50cm thick that has been produced by mixing, filling or by contamination of land surface in urban and suburban areas.”
- undisturbed but altered by urban environment
- Anthopogenic soils

Effects of urban environments on soils and ecosystem processes
-Urban soils are usually compacted, eroded and of low OM
Generally thought of as disturbed and infertile when compared with the native soils they replaced
Numerous studies have revealed a surprising level of biological activity in urban landscape
- accumulation of heavy metals and base cations
- nitrogen deposition (atmosphere, water)
- phosphorus dynamics biological changes in soils associated with chemical changes
- enhanced potential for invasion of exotic species in urban species

Uses of organic wastes for urban agriculture
- urban settlements are importers of natural resources and exporters of wastes to landfills/rural areas
- Cities are abundant sources of solid organic wastes containing nutrients for soils and for animals
- At present only a tiny percentage of urban organic wastes is recycled
- low-cost technologies for urban agriculture: Composing, vermiculture, animal feed after elimination of pathogens (pig, fish farming)

Composting
organic waste collected from city households and biosolids (sewage sludge) as resources to create compost

How does it work?
natural process
micro-organisms breakdown organic materials.
heat is generated with pile temperatures often reaching 70C
The high temperatures achieved are very important for sanitizing the waste as they kill off almost all the pathogens including highly resistant eggs

Compost to reestablish drainage
- rebuilding soils to take advantage of their free ecosystem services
- Improving soil infiltration and contaminant binding capacity by using composts “bioretention systems”

Wastewater
- wastewater is important for irrigation in many urban and peri-urban locations
- treated water is limited by competition with other water users or by price
- it is also a useful source of nutrients, and in some cases may eliminate the need of fertilizers
- pathogens on vegetables grown with untreated wastewater can cause gastrointestinal ailments

Take Home Message
Poverty and malnutrition are becoming increasingly urban: Improved urban food production is necessary for food security and decrease malnutrition in cities

Complementary to rural agriculture to feed on growing population.

On a predominantly urban planet, cities adopt systems to assure their own sustainability in the long term.
→*Urban outputs will need to be regarded as crucial inputs*

Basics mechanisms underlying climate variation and its importance for crop production

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There are huge variations in yields across the globe because of:
- heat
- day lengths
- precipitation
- growing season length
- elevation

What is the difference between weather and climate?
Weather is short term
Climate is long term

What causes changes in weather?
- Result of rapidly developing and decaying air movement
- Changes in pressure

What are the major climates?

Climate	Characteristics
Tropical	• Monthly average temperature > 18C • No winter season • Strong annual precipitations
Dry climate / Desert	• Annual evaporation higher than precipitation • No permanent rivers
Hot moderate climate	• The 3 coldest months average a temperature between -3C and18 C • Hottest month average temperature >10C • The summer and winter seasons are well defined
Cold moderate climate	• Coldest month average temperature of the coldest month <-3C • Hottest month average temperature >10C
Polar Climate	• Average temperature of the hottest month >10C • The summer season is very little different from the rest of the year

1. Latitude affect temperature and seasons
- Angle of earth relative to the sun (intensity of radiation)
- Distance to sun

Variation in air temperature causes air movement
-precipitation and moisture-
- precipitation and moisture
- Water holding capacity of warm air is greater than for cold air
- When air becomes cold, water condenses and forms droplets

Trade winds: the resulting bands of cloudy and rainy weather near the equator create tropical conditions

2. Elevation and precipitation

Air at higher elevations are cooler.
Pressure is lower so gas molecule expand
Rate of motion of atmospheric gazes is lower = cooler temperatures

3. Distribution of water bodies - currents
- Water has a higher heat capacity than land: cools and warms up more slowly
- Difference in water and land temperature causes air movement thus affecting wind direction and precipitation

- Cold water currents contribute little moisture to surface air masses (deserts along coasts)

We have technologies to overcome climate restrictions

How does climate influence crop management?
- Irrigation
- Pest levels
- Plant varieties, when to plant, till or no till etc
- Rotations

Crop grown and rotation
- Crop requirements (water, light, temperature)
- Degree days and length of the growing season
- Cropping system management practices
- Pest/disease present

Maize has high requirements to reach maximum yield potential
- Precipitation
- Light
- Temperature and growing season length

What is the optimum temperature to grow corn?
- 24-30C (high if moisture is not limiting)
- low night temperatures damage photosynthetic apparatus
- high temperatures increases respiration - pollen viability
- Cold soil temperatures delay emergence and early season growth

Precipitation and yields
Amount:
- Effects biomass accumulation/transpiration requirements
- Effects nitrogen and other soluble nutrients availability
- Correlated to sunshine availability

Distribution:
-Temperate vs tropical
- Prevalence and intensity of drought periods
- Crop development stages

Interaction between temperature and water use
Adapted to a wide range of temperature - why it is in so many agrosystems
Water demand varies during growing season

Suitability of the Midwest Corn Belt

- precipitation is key
- a lot of precipitation is needed and there is a lot in the corn belt

Is the wet or dry season more productive?
For rice, you will have a bigger yeild in the dry season.
The difference? Sunlight!

Light
- Day length - mechanisms to control flowering date
- Cloud cover - radiation available for growth

What is different between system of growing maize in Sierra Leone and Ontario?
Management
- Fertilizer application and use efficiency
- Leaching (N), erosion (P)
- Planting date/ harvesting, grain quality
- Tillage and cover crops
- Pest and diseases pressure and management

Ecological processes (microbes activity)
- N and C cycle
- Soil water holding capacity
- Fertility (acidity, toxicities, deficiencies)

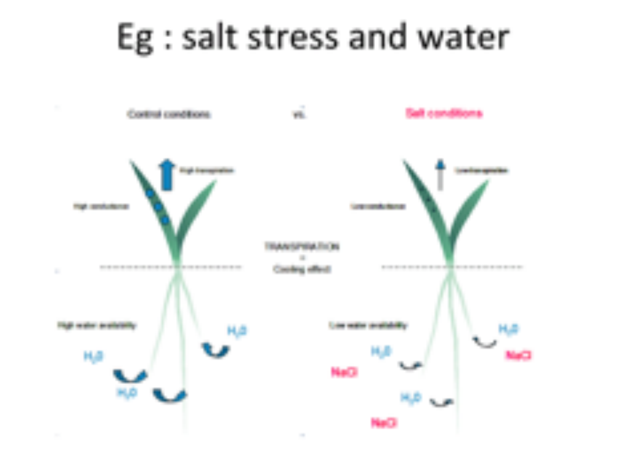
Resources, use efficiency and competition

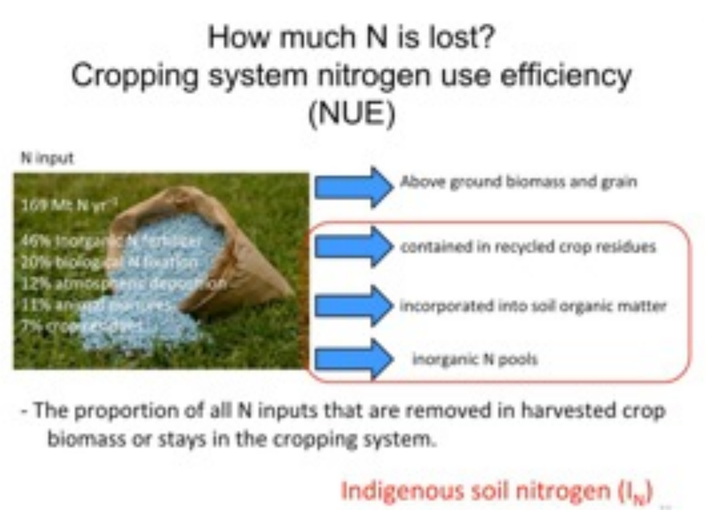
What are the major resources needed to grow crops?
- Light
- Water
- CO_2
- Genetics (seeds - biomass)
- Labor
- Fuel
- Soil
- Nutrients (Fertilizers, manure)
- Biota (O_2, C)

Agroecosystems rely on natural processes for maintenance of their productivity.

Major ecological recycling processes in field - soil??

Flow of resources is highly variable
- soil biota activity -
- In time
  - seasons
    - resides available
    - rotation, management
    - grazing
- Spatially
  - slope
  - erosion
  - strata





How to calculate Nitrogen fertilizer uptake/recovery efficiency (REN)

- Two methods, both have inherent weaknesses.
  - Isotope method: Uses 15N labeled fertilizer to estimate crop recovery of applied N
  - The ‘N-difference’ method: is based on the difference in N uptake between a crop that receives a given amount of applied N and N uptake in a reference plot without applied N

Overall:

- Agriculture is less dependable on natural processes
- Agriculture alters the natural cycling of resources (biomass removal, bare soils during winter...).
- Temporal and spacial imbalance in resources (eg - timing of N release into the system)

Carbon Cycling and it’s Significance for Agricultural Production

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Organic - inorganic carbons
10 million compounds

- **INORGANIC CARBON:** compounds derived from minerals in the Earth (Carbon dioxide, carbonate, bicarbonate...)
- **ORGANIC CARBON:** compounds derived from plants or animals

Inorganic Carbon

- **Carbon-oxygen compounds**

Carbon dioxide (CO_2)
Carbonic acid (H_2CO_3)
Bicarbonate (HCO_3^-)
Carbonate (CO_3^{2-})

- **Carbon-sulfur**
- **Carbon-nitrogen**

Synthetic carbon compounds

- artificially man-made compounds with carbon elements in it.

What are the products of decomposition (aerobic soils)?

- Oxideized to produce CO_2, water, OM and energy (478kJ.mol-1 C)
- Protein → amino acids which will further mineralize
- Decomposer biomass

Factor controlling rates of decomposition

From days to years
1. Environmental conditions in the soil
- pH, soil moisture, aeration, temperature

2. Quality of the residues (food source for microorganisms)
- Physical condition, composition

Accumulation
Balance between plant production and use by soil organisms
- Influence of climate (Temp, moisture)
- Influence of agricultural management
    - Tillage
    - Rotation (including cover crops)
    - Residues quality, plant nutrients and amount of residues
    - Biomass production
    - Erosion
    - Nitrogen, fertilization

Controversy - effects of synthetic fertilizers
“Fertilizer is good for the father and bad for the sons.” - Dutch saying
- Synthetic nitrogen makes plants grow bigger and faster. They pull out more CO2 from the air to be stored in the soil
- nitrogen fertilizer stimulates soil microbes, which feast on organic matter. Over time, the impact of this enhanced microbial appetite outweighs the benefits of more crop residues

In other words, synthetic nitrogen broke down organic matter faster than plant residue could create it.

Recommendations for management in a C. System
- Continuous supply of organic matter
- Sound crop rotations that return a variety of residues to the soil
- Adequate N fertilization is requisite for adequate OM levels
- Maximum plant growth will increase the amount of OM added to soil from crop residues
- Manage tillage appropriately, decrease fallow
- Consider perennial vegetation (biomass crops)
- Reducing erosion losses of soil

The ability of field crop production systems to **mitigate, adapt** and **recover** from environmental stresses

Variation in soil moisture

Wednesday, April 16, 2014

Too much or too little

Nitrogen resource, losses and utilization efficiencies in agroecosystems

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Why do we need to manage N?

- Nitrogen is an essential plant nutrient
- Nitrogen is extremely mobile and can be lost to the environment in various forms
- Nitrogen is energy intensive to produce
- Nitrogen is expensive

How can atmospheric nitrogen be available to crop?

- Atmosphere: 78% N_2
    - Biological fixation
    - Chemical fixation (N_2 is combined with H_2)

      Hydrogen → NH_3 ammonia

Nitrogen is energy intensive to produce / expensive

- Stability of the N bound (16ATP!)
- About 1/2% of the world's annual energy consumption is used to produce NH3 (or roughly 1% of annual global CO2 emissions)
- Energy efficiency in the manufacturing of nitrogen-based fertilizers has significantly improved since the early 20th century
- Uses natural gas as the primary hydrocarbon stock (or coal in China)- trend with gas prices

Nitrogen exists in many forms and several physical chemical and biological processes affect its ability to plant.

Nitrogen use efficiencies
- Cropping system use efficiency
- Fertilizer use efficiency
- Physicological use efficiencies

Physiological nitrogen efficiency
2 factors

How can NUE be improved?
Efficiently utilize both indigenous and applied N
- Sustain I_n pool
- Greater RE_N and PE_N
- Need for **greater synchrony** between crop N demand and the N supply from all sources throughout the growing season
- Sound management recommendations
- Take into account the biophysical determinants of crop nitrogen requirements (climate, yields)
- Decrease losses

Nitrification Inhibitors
- Chemicals that slow down or delay the **nitrification process**
- Killing or interfering with the metabolism *Nitrosomonas* bacteria
- Decrease the possibility that larger losses of nitrate will occur before the fertilizer nitrogen (ammonium) taken up by plants
- Nitrification of applied ammonium = 2-3 weeks
- Delays the conversion of ammonium nitrate for 4 to 10 weeks
- N-Serve and Dwell : corn, sorghum, wheat, cotton , rice, and other crops
- Fall - Spring

Effect of green manure (legumes) on cropping system NUE
Input ~ losses from the system
Sustainable INPUT of N into the system
- Legume provides additional nitrogen from N2 fixation directly to the next crosss of for storage in the organic pool (part of I_N).
- Can reduce N application by 40-70kg N ha^-1 after legume cultivation

- 15% to 28% of N is taken up by the first succeeding crop , most of the remaining N is stored in the soil organic nitrogen fraction
- Recovery of organic N source occurred over several years

Decrease N losses form the system

- Release must be synchronized with N uptake form the following crop
- Depends on mineralization rates
  - management practices (tillage)
  - environmental conditions (TC, pH, moisture)
  - residue quality (especially C/N ratio)
  - killing time of the legume
- Can mitigate mitrate leaching
- Legumes might be less efficient at catching soluble nitrogen during growth than cereals cover crop species
- nitrous oxide emissions during residue mineralization?
- Under-estimating N from roots decomposition and mineralization

Water resources and use efficiency

Challenges?

- **Large use of fresh water:** ~70% of fresh water resources globally
- **Climate change:** exacerbate the present shortages of water, and is likely to increase drought
- **Needed for food production:** Irrigated areas accounted for approximately 18% of the worlds cropped land in 2003 ~ 40-45% of the global food
- **Increase pressure on resources:** Irrigation in still increasing globally, high losses.
- **Competition** with industry/ Future legislative restrictions

Control of evapotranspiration?

- 1) Available soil moisture
  - Weather effects on rainfall and evapotranspiration
  - Water infiltration and retention

    - Plant rooting characteristics
    - Water holding capacity (soil texture, soil structure, compaction, soil depth, %OM)
    - Depth to water table

- 2) Water deficit and plant water stress
    - Soil moisture < crop requirements

Crop responses to water shortage

Escape the drought period	**Recover from drought**	**Avoid having a low water status during drought**	**Tolerate drought by sustaining plant mechanisms and growth during drought**
Crop duration	New productive tillers/ leaves	Extract more water from the soil (root traits)	Increase WUE
Time to flowering		Adapt stomata aperture and leaf rolling to reduce water loss	Osmostic adjustment
			Cell protection

- 3) Climatic conditions
- 4) Radiation - energy
- 5) Plant canopy development
- 6) Plant physiology and characteristics

Field or Cropping System Water Use Efficiency

- WUE = Dry matter yield per unit of water transpired (plant only)

$$WUE = \frac{\text{Crop yield (kg)}}{\text{Water consumption } (m^3)}$$

Yield = Water use x WUE x HI

HI= harvest index is the ratio of harvested yield to total above ground biomass

Cropping System level

Yield = (rainfall - losses form soil and non-crop species) x transpiration efficiencies x HI

Key elements of dry land farming

Yield = (rainfall - losses form soil and non-crop species) x transpiration efficiencies x HI

- Capture and conserve moisture
- Effective Use of Available Moisture
- Soil conservation
- Control of Input Costs

Options to DECREASE LOSSES IMPROVE USE OF RAINFALL?

- Control of unwatered vegetation
- Fallow periods (no cover drops in dry land)

Roots!

- Crops may not use all the water available in the soil profile because of restrictions to root growth
    - Physical (eg. Compaction)
    - Chemical (acidity, boron or aluminum toxicity)
    - Biological (root diseases, insects, nematodes)
    - Poor rotations
- Enhancing infiltration, water retention.
    - Soil structure
    - Organic matter
    - Root channels, microbial activity
- Planting dates: closely match incoming rainfall and reduce soil evaporation
- Planting density and row width
- Fertilizer use

Decrease soil evaporation

- Vegetative mulches
- Paper and plastic mulches
- Crop residue, minimum tillage and conservation tillage

Agroecology for a cultivated planet

Wrap up

AGROECOLOGY
- Applying **ecological concepts** to the design management of sustainable agroecosystems.

Symptoms
- Fever and chill
- Headaches…

Causes
- Exposed to virus
- Wick and tired
- Low immunity
- Unbalanced nutrition

We usually treat symptoms
More efficient to address causes over time

Ultimate Goal: Goes beyond using alternative practices

To eliminate the use of agrochemical inputs through change in management to assure
1) Adequate plant nutrition
2) Sufficient water supply
3) Plant protection (pests, diseases)

Productivity == Sustainability

4 Basic agroecological principles

Longer and more diverse crop rotations
Cover crops, intercropping, relay cropping
…
Use of legumes green manure (natural N fertilizer)
Reduce tillage, use mulches
Maintain return of residues
Manure application, composts, biosolids
…
Introducing and/or conserving natural enemies

Corridors and refuges for wildlife

…

Soil and water-conservation
Resilience and stability to biotic and abiotic stresses
Reduction of erosion potential and losses
Maintain fertility and productivity
Decrease in chemical input

Role of GMO crops?
- Organic vs conventional
- Technology or its usage?

Next generation?

New technology coming our way
- Rhizobium - N2 biological fixation
- Biofertilizers: Growth promoting bacteria, N fixing
- Biopesticides: Root cyst nematodes (*pastueria penetrans*)

Remember!
Agroecological innovations in crop and soil management show great promise for
- improving the resource efficiency of agriculture
- maintaining the benefits of intensive agriculture
- while greatly reducing harm to the environment

Communicating Sustainable Agricultural Practices

Claudia Schmidt

George Morris

- Cattle feeder and cash-crop farmer from Merlin, ON
- As president of the CCA, he introduced the Canadian live cattle grading system
- The holder of an honorary doctorate from the University of Guelph and a member in the Canadian Agricultural Hall of Fame
- Donated much of his estate to pursue his visions through the George Morris Centre

What does Agri-food Sustainability mean?

Sustainability

- Good producers and grocery retailers increasingly show that they source sustainably
  - Differentiation
  - Competitive advantage
  - Investors
  - Customer demand
  - Improve business efficiencies
- Agricultural producers will have to respond

3 Pillars of Sustainability

Environmental

Preserving environmental resources

Social

Social relations between farmers and rural communities; ensure and possibly create employment; animal welfare

Economic

Ensure the economic viability of farming systems at the local farm level

Certifying Sustainable Practices

Implementation of Programs

- Access to customer (proof of certification)
- Voluntary program - customer (logo on product)
- Voluntary program - conviction
- Monetary support (?)

Certification Programs - Examples

Customer developed

Tesco's Nurture

Whole Farm

GlobalGAP

Attribute Specific

Certified Humane (Animal Welfare)

Country specific

UK's Red Tractor

Commodity specific

Certified Greenhouse

Canada - Agri-Food Initiatives

- Grain Farmers of Ontario
- Pulse Canada
- Grains Roundtable - Sustainability Working Group
- Dairy Farmers of Canada
- Canola Council of Canada
- Local Food Plus
- Environmental Farm Plan

Environmental Farm Plan

- Environmental Farm Plan (EFP) is a farmer developed educational tool to understand on-farm environmental improvements
- Self administered questionnaire
- Financial support for BMP implementation
- EFP addresses Environmental Sustainability
- Has not addressed:
    - Animal Welfare
    - Labor Standards
    - Third party verification
    - Metrics

Issues

Challenges

Confusion around three pillars of sustainability
Environmental
Social
Economic
Cost of certification
Audit
Record keeping
Multiple programs
Lack of auditors
Change in requests

Market Access Barrier
Market access: ‘allowed’ to deliver to a specific customer
Retail level
Contraints
Infrastructure
Personnel
Financial
Country level

Europe vs Canada

European Union

- Europe - Market leader in sustainability?
- Retailers/manufacturers drive agenda
- Germany
    - Organic agriculture
    - Whole farm sustainability schemes
    - Uptake
    - Market demand

Canada
- Early phase
- Respond in anticipation of customer demand
- Nice to have vs must have?
- "Made in Ontario" commodity sustainability certification program: Grape Growers of Ontario and Wine Council

Conclusion
Sustainability (with all its different interpretations) is here to stay

Farm level:
Stay informed!!

Industry Level
Protect market access
Increase adoption of sustainable practices
Value chain approach

Agroforestry Systems

Providing Ecological Goods and Services

Agroforestry:

"Incorporation of trees into farming systems"

a.k.a. Farming with trees!

Types of Agrosystems:

- Forest Farming Systems - Commodity

"Non-Timber Forest Products" :

- maple syrup
- christmas trees
- ginseng
- shiitake mushrooms
- pharmaceuticals

- Windbreak Systems - Trees around fields

optimal porosity = 40%

- Silvopastoral Systems - Trees, animals and pasture

main reason = animal welfare

shade etc.

- Integrated Riparian Management Systems - Trees on stream banks

drops stream temperature

leaves drops and add organic matter for fish and insects

- Intercropping systems - Trees and crops

growing trees in parallel rows with a crop

yields are virtually the same with wheat and beans however lowers with an intercrop of corn (C4, needs more light)

earthworm density is dramatically increased

intercropping basically changes the entire energy flow

- [Bioenergy Systems] - Trees for energy

Biomass Crop Production

Wednesday, April 16, 2014

What is biomass?

Plant material for the purpose of meeting fibre and fuel requirement.

What are the potential uses for biomass

- ethanol
- heating
- electricity
- fibre
- biochemicals

What are the types of biomass?

1. crop residues 2. biomass crop

What are the potential agroecological impacts of biomass production?

It will have a major impact (think of coal companies switching to biomass).

Crop residue biomass

- Corn stover

- can get too wet to harvest (late fall)
- contaminated material

- Corn cobs

- clean material
- still has moisture issue

- Soybean residue

- primarily for bedding
- still to wet
- not clean enough

- Wheat straw - also many other uses (compost, bedding etc.)

- harvested late july/mid-august
- dry enough, clean enough
- so many other uses that biomass cannot compete with

Agroecological impacts of crop residue removal

- Nutrient removal
- Soil erosion
- Soil organic matter reduction

you don't remove residue from a crop, you remove residue from a rotation

Dedicated biomass crops

- Hemp
- Energy maize
- Sorghum
- Short rotation woody - willow, poplar
- Perennial C4 grasses - miscanthus, switchgrass, other native grass species

Miscanthus spp.

Miscanthus comprises a group of more than 10 grass species, most of which are native to Asia.

Giant Miscanthus is a sterile hybrid, C4, perennial warm-season grass believed to have M. *sinuses* (a diploid species) and M. *sacchariflorus* (a tetraploid species) as its parents

25 tonnes dry biomass per year of yield (super high!)

Switchgrass (*Panicum vigatum)*

- Native to North America
- Propagated by seed, cross pollinated
- Perennial warm-season (C4) grass

Agroecological impacts of dedicated biomass crops

- Depends on
    - Annual vs perennial
    - Yield potential of the crop
    - Inputs required
- Depends on crop being displaced
- Depends on land type used

Synergies of linking ruminants, forages and soils

Focusing on Farmland

Farm land asked to provide 4**F**'s **F**ood, **F**eed, **F**ibre and **F**uel (energy) and **F**un

Our responsibility is to help maintain **F**unctionin**g** Farm Ecosystems

Ruminant Animals

- Microbial populations housed by the ruminant in the first 3 stomach compartments, ferment roughage (cellulose) as a source of energy
- End products of fermentation provide nutrients to produce meat and milk
- Ruminant manure and microbes stimulate soil

Feed Conversion Ratio (FCR)

FCR=mass of feed (dry) / body mass gain (wet)

e.g. Chicken was 6/1 and now <2/1

FCRs close to maximum efficiency

Prior to 20th century, most animals only fed human **in**edible feed. Humans ate only human edible food.

After 21st century, accept lower FCR and only use human **in**edible feed for livestock?

Forages

- Cheapest feed sources for ruminants, for effective forage based meat and milk production
- Improve soil, reduce erosion, reduce nutrient leaching, contribute N (legume forages)

Clover/Alfalfa Benefits for Soils

- Increases aggregate stability
- Improves water holding capacity
- Erosion prevention
- Builds soil tilth
- Decreases soil compaction
- increases microbial activity
- Increases soil organic matter

Soil Organic Matter (SOM): Foundation of Agriculture

- SOM is added with green manures, brown manures and crop residues
- SOM binds soil particles for good soil structure
- SOM matter allows infiltration, sustains crops in floods and droughts
- SOM improves nutrient availability to crops

Forages as Biological Infrastructure of Agriculture

- Well manages forages provide cost effective **feed**, soil cover, C, nutrients +
- Cover crops are **soil builders,** soil cover, C and nutrients +
- Governments pay for roads and bridges. Incentives for forages and cover crops?

- Aerial photos in 1930's - smaller fields and more fencerows to slow ater run-off. More pastures and woodlots, less erosion.
- Today, only 1% of land in MVCA watershed is pasture and 68% in row crops in large open fields.
- Biomass crops on sensitive land to breakup large fields?

Removing Corn Stover and Wheat Straw

- Removal from arable land for bio-products and bio-fuel, reduces SOM and thus resilience
- If remove form farm, how will SOM be maintained and what will the impact be on erosion?

Productivity of eroded soil…. will decline even if fertilizer is added or if the eroded soil is irrigated

Observing and Caring

- Erosion control practices tend to increase on farms:

1) with farmers mostly on the farm
2) organized as family units

Diet and Land Resources Requirements

- Measured impact of fat and meat consumption on the land requirements of food production in NYS
- 42 diets, each with 2308kcal/d
- Diets ranged from 0 to 381g/d of meat and eggs and 20 to 45% total calories from fat

Gospel According to Martin KEEPS YOUR SOIL COVERED

i) Cover crops and forages in rotations when cash crops are not growing
ii) Under-seeded cereals
iii) Mulches/inter-seedings with growing cash crops
iv) Winter cereals
v) Agro-forestry

Diet and Land Resource Requirements

- Vegetarian diets generally support more people
- Meat in diet explains most variability for land required per capita (97%) and carrying capacity (87%)
- Diets with modest levels of meat and fat can feed a few more people than vegetarian diets of high fat
- 3x potential number of people can be fed with more efficient diet

How can a forage crop be used on organic stockless farms?

(without removing for sale)

- wheat yield increased as alfalfa mulch rate increased, mainly as a result of mulch-supplied N
- soil moisture was conserved
- weeds were suppressed

Vision to Sustain Food

A food system, based on healthy soil, clean air and water, minimal waste and regenerative energy, to support profitable and resilient farming and fishing communities and a healthy food supply for all.

Social License to Operate and Nutrient Flow in the Livestock Sector

Premise of Rules and Regulations

1. *If it is not forbidden, it is permitted.*
2. *A population can only have rules implemented upon them if they are willing to accept them.*

- Agriculture is no exception
- 'Social Licence to Operate' becomes important

What does this mean to animal ag?
- Consumer Choices
- Government Regulation
- Environmental Issues

- Animal Welfare
- Relative acceptance of livestock industries

Social Licence to Operate

Will be given by the following mechanisms

- Public policy (funding programs, regulations)
- Market signals
- Will differentiate between livestock species
- Will apply to welfare and environmental topics

Nutrient Flow in the Livestock Sector

(aka - nutrition and production primer)

Concepts to cover

- Nutrient in practice (as opposed to nutrition)
- Monogastrics vs. Ruminants
- Feed Efficiency, Biological Efficiency

Nutrient Hierarchy

- oxygen (air quality)
- water (cleanliness, harness, purity)
- **carbohydrate (CHO: sugars, starch)**
- **protein, crude protein (CP=N x 6.25)**
- vitamins
- minerals
- fats*

Energy Level Spectrum (forage vs. grain)

Forage
lower energy
higher fibre
lower gains
longer DTM

Consequences of Nutrient Over-Supply

- Excess dietary protein = excess manure nitrogen
- Excess dietary phosphorus = excess manure P - (organic or inorganic P)
- Excess fibre = Excess GHG (greenhouse gases)

Monogastrics vs. Ruminants

Some monogastrics can accommodate highly fibrous feeds (eg Horse, rabbit)	Primarily fibrous feeds. Highly co-evolved with grasses and other leafy plants
High tolerance for starches and sugars	Low tolerance for starches and sugars
Digestion primarily by animals own means (enzymatic)	Fermentation followed by enzymatic harvest of fermentation products
Requires high quality protein Can only manufacture protein (if) by fecal recycling	Tolerates very low quality protein. Manufactures high quality protein.
Inherently superior feed efficiency per unit weight feed	Lower feed efficiency, but capable of thriving on marginal plant materials

Rumen Chemistry

→

Feed Conversion

- Feedlot cattle
- Veal (grain fed)
- Lamb

- Swine
- Turkeys
- Broilers
- Fish

Maintenance *vs* Gain

- 34 days at 3# per day requires a total of 420.2 Mcal Energy for 100# of gain
- 100 days at 1# per day requires a total of 772.0 Mcal Energy for 100# of gain
- 3 times rate of gain requires 5/8 total E

Growth and Composition

Lean gain is more efficient that fat gain

Challenges to Livestock Agriculture:

- use technologies and tools to continue incremental improvements (R &D)
- Maximize protein production from declining resources (R&D, Industry efficiency)
- Utilize resources which do not degrade the environment (R&D, Policy)
- Provide clarity on which production systems (species?) have the desired net benefit. (r&D, Industry efficiency, policy)

Nutrient Flow in the Livestock Sector

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Sustainability and Aquaculture

Future Supply

Aquaculture is the fastest growing food sector on the planet

- By 2020, 1/2 of all fish and seafood will be derived from aquaculture
- **At 50% in 2012**

Benefits of Aquaculture

- Economic development in rural and coastal communities
- Year-‘round operations
- Capability to produce to meet market demand and consumer needs
- Expanding domestic and international markets
- Enhanced balance of trade (exports)
- Non-extractive, renewable resource industry
    - i.e. sustainable development
- Considerable un-developed potential
- Augments productivity of entire fishery sector

Output by Province

- BC leads provinces
- NB is second
- NL and NS also mainly salmon producers
- PEI mainly muscles
- **ON, QC, & Prairies produce mainly trout**

Why Rainbow Trout?

- Culture techniques, based on more than 100 years of research and practice, are well established;
- Domesticated strains of trout have been bred to improve performance and yield;
- Nutritional requirements are well defined and efficient commercial feeds are available from several suppliers;
- Water temperatures and the biophysical resource base throughout much of Canada are near ideal for the species;
- An established market exists for rainbow trout

- Naturalized species in most parts of the country and thus poses little to no genetic threat to feral populations

The abundant potential…

- 20% of the worlds freshwater is in Canada
- Plentiful biophysical resources
- Developed culture technology
- Still not meeting domestic demand
- Substantial export potential with proximity to the U.S. market
- The industry has the experience, expertise and the desire to support development

Rainbow Trout / Arctic Char Production Cycle

- Ova
    - Commercial hatcheries
    - Selected brood stock/strains
    - Hatch in 30-100 days
- Sac Fry
    - Absorb nutrients from yolk
    - ~60 days
- Fingerlings
    - Moved to large tanks or cages at ~10-20 grams
- Harvest
    - On-growing for 12-16 months
    - 0.9 - 1.5 kg's
    - Two 8-12 oz fillets per fish

Floating Containment

- Relatively low operating costs compared to land-based
- Very energy efficient - low pumping costs

- Low environmental impact due to manure recovery and removal
- Ease of operation and management, depending on technology can allow for a greater degree of stock management than net pens
- Flexible design - units can be added and moved around as needed
- Depending on the site it is possible to manage water temperatures by dual draws pulling from different depths

Open Net Pens (Cage Culture)

- Manitoulin Island and Parry Sound
- Lower unit costs for capital and operation than land-based
- Need to locate in more remote areas to avoid potential user conflicts
- Site selection vital as many sites have high surface temperatures during summer months
- Need to be sufficiently large to be economical (at least 400 tonnes per year)
- Location, location, location - not in a small confined hypolimnion area and location to minimize risk of ice movement and severe weather

Open water net pen farming - early 80's

80% of Ontario's rainbow trout

10 farms - 4 first nations

~800,000 to > 3 million lbs/farm

Having trout farming in lakes

Summary of Results

- Abundance of most fish populations increased during the 5 years of cage culture
    - No negative impacts
- Lake trout
    - Fatter
    - Grew faster
    - Earlier age of sexual maturity

- More females spawning each year
- Annual survival increased
- Increased “recruitment”

Principals of Nutrient Management

4-R Approach:

- Right Product
- Right Rate
- Right Place
- Right Time

Best approach for all nutrients, but requires an understanding of nutrient utilization and pathways for loss

Nutrient Management

the science of managing nutrients in ways that:

- optimize beneficial use of nutrients for crop production (economic benefit)
- minimize environmental impacts of nutrients
- identify risks….

Soil Balance

Physical	Biological	Chemical
good soil structure	high OM levels in soil	pH balance (6.5 - 7.2)
no compaction	high earthworm population	Macro-nutrients in balance
	variety of micro-organisms	

Other Sources of OM (& nutrients)

- crop residues
- cover crops
- Manure
- Biosoilids
- Biosolids pellets

- N-Viro
- Biochar
- Digestate
- Compost (manure & principal)

Manure Composition

nutrients in manure vary with:

- type and stage of growth of livestock
- ration
- amount and type of bedding material
- type and method of storage

Liquid manure has higher portion of nitrogen in quickly available form while solid manure has more nitrogen tied up in the organic materials which will cause slower release.

Phosphorus is tied up with solids; Potassium is higher in fluids.

Taking a manure sample for analysis

Manure testing can Increase Nutrient Utilization

- sample regularly - 2x per pit (at 1/4 and 3/4 empty) Or, sample on a per field basis
- Include C:N ratio in the analysis (especially for solid manure)
    - Greater than 30:1 indicates potential N tie-up
    - Less than 10:1 indicates quick potential cycling of N

Conductivity = ions = salt level = burning up plants!

Micro-Nutrients in Manure

- Micronutrients closely related to livestock rations - large variability between farms
- Regular manure application = low probability for need of commercial micronutrients (including sulfur)

Manure - more than just a source of nutrients

Different amendments have different benefits to soil.
picture from slide

Soil Organic Matter

The Very Dead - 40-45%
Very stable (Humus)
Increase water holding capacity

The Living - 10-15%
Active Nutrient Cycling

The Dead - 40-45%
Active Organic Matter
Food for Soil Organisms

Nutrient Availability - Analogy for phosphorus
Phosphorus is tied to soil particles and moves off fields through runoff or erosion
40% available immediately
40% available later
20% never available

Organic Material Nitrogen Availability to Crops

Total Nitrogen = Organic N + Ammonium + Nitrate
Availability of the Nitrogen depends on:

1. Type of organic matter
2. Amount of Nitrogen
3. Organic nitrogen component
4. ….

Incorporate Manure to Minimize Ammonia Loss

What we know:

- the sooner incorporation occurs the lower the loss
- volatilization of ammonia is the highest wham manure is surface applied to bare soil, during hot dry and windy conditions