

Environment and Soil

Lecture for Graduate Students

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2015

International
Year of Soils

Extended to 2024 as
International Decades of Soils

What is Soil ? (1)

Soil is a Natural product.

- Soil is created from minerals, water, air, and biota under the interrelationships between these factors, reflecting the surrounding environments on the surface of earth.
- Soil is one of the bases for all the living activities on the earth.

Soil is a product of natural environment.

- Geology
- Land shape
- Amount and quality of water
- Climate and meteorological condition
- Vegetation
- Soil microbes, Soil animals
- Time

Definition of Soil by JSSPN

(Interim, unofficial translation by K.Tsutsuki)

- Soil exists in the surface or below shallow water on the surface of earth. Under the interaction of the weathering of rocks, transportation by water and wind, sedimentation and biological processes, organic matter and minerals are mixed and constituted naturally. It supports the life, holding and circulating substances on earth, but changes according to surrounding environment.

What is Soil ? (2)

Soil is a Man-made product.

- Human can work on soils, and change the soil properties so that he can obtain his desired products.
- → Soil is a basis for agricultural production.

Soil is an artificial product for human

- Soil maybe deteriorated depending on the human activity on it.
- It is due to the bias in the purpose of human, and also because human does not have a long vision.
- Human can not create soil. He can only change it.

Soil is controlled by human environment

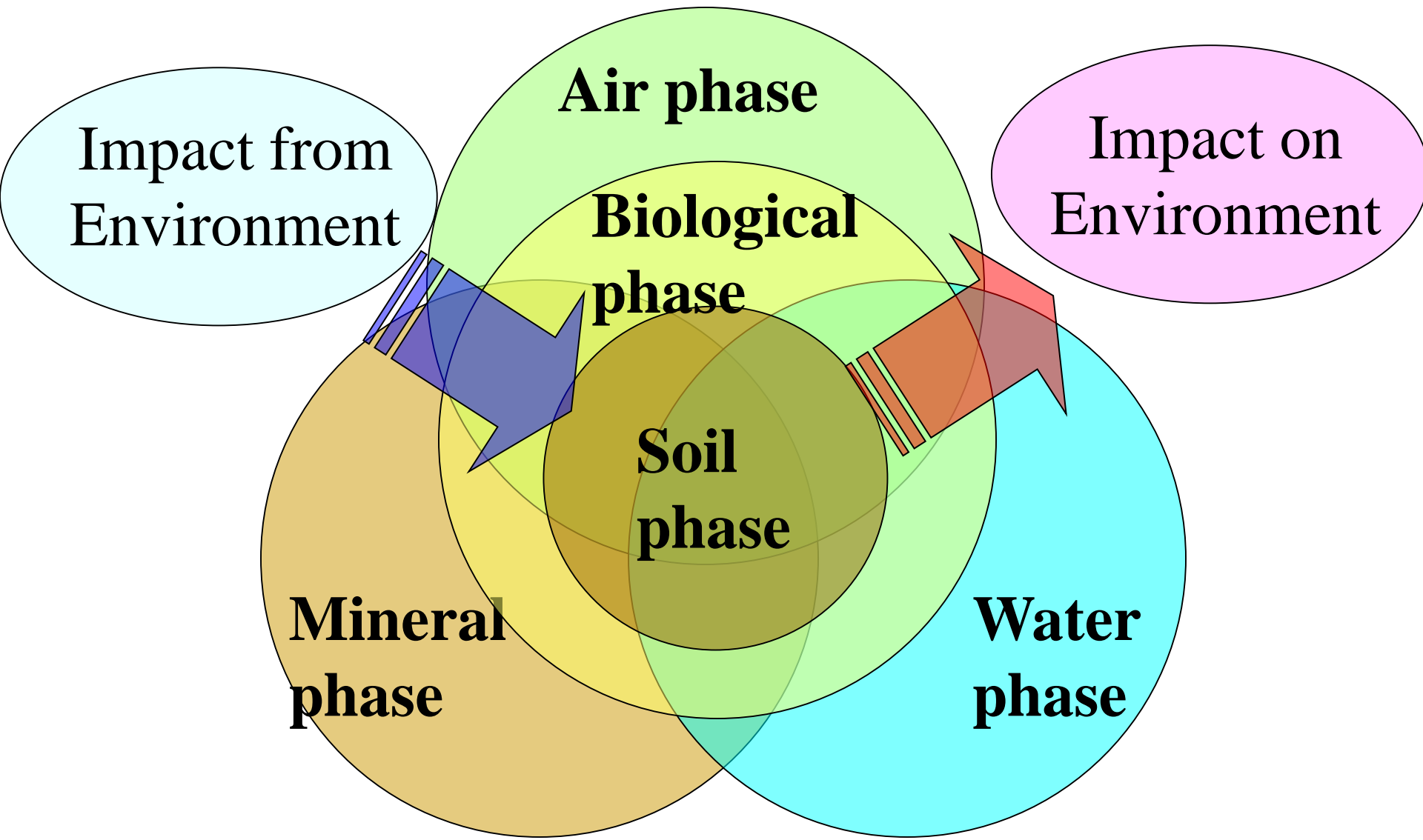
- Agricultural land development, irrigation, and drainage
- Crop cultivation
- Plowing (Man ▪ Animal ▪ Machinery powered)
- Organic matter application
- Fertilizer application
- Weed and pest control
- Soil contamination (Fertilizer, pesticides, radioactive pollutants)
- Agricultural policy. State of agriculture in national consensus.

We are making light of soils

- Soil is educated little in the Japanese compulsory education.
- It is due to the guideline for teachers issued by the ministry of education.
- Education of soil is left to the hands of individual teachers, but without the official manual and sufficient time, it is difficult.

Why soil is not respected in education?

- Though soil exists universally, it also differs from place to place.
- Soil is composed from various constituents.
- Soil is too complicated and it is difficult to propose a fixed educational method or a scientific study method.
- Functions of soils are deemed to be replaceable by another means.



Evaluation of Soil Phase

History of Earth and Soil

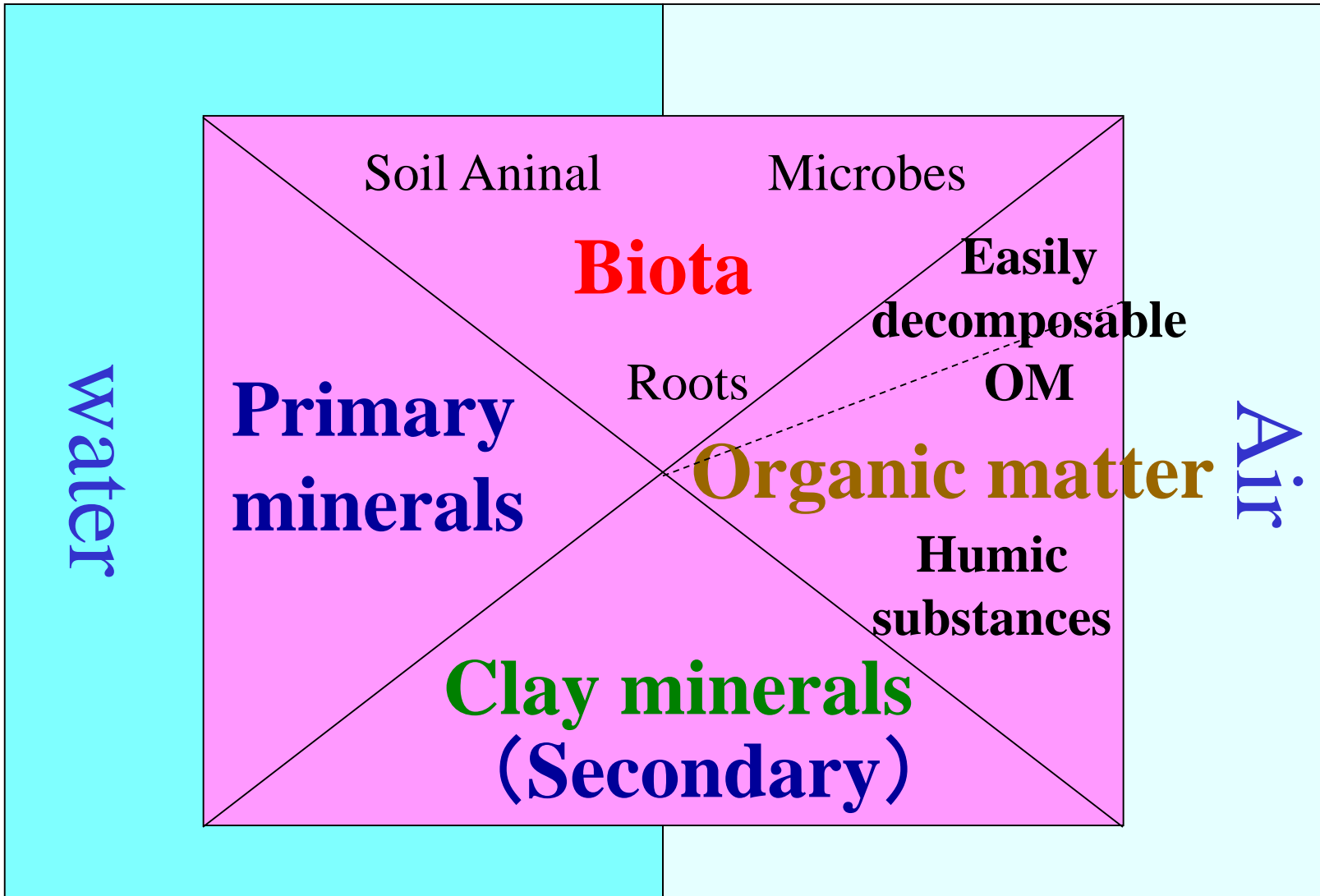
Years B. P.	Events	Air	Soil
4.6 billion	Birth of Earth		
4.0 billion	Sea of HCl	CO ₂ 97 %	
	Dissolution of minerals, neutralization of sea water		
	Precipitation of CaCO ₃ in the sea (Lime stone)		
3.8 billion	Development of aquatic lives		
2.0 billion	sea algae (cyanobacteria, stromalite)		
		O ₂ 0.2 %	
0.6 billion	Lichen, terrestrial lives.	O ₂ 2 %	Initial Soil Formation
0.4 billion	Landing of Plants	O ₂ 21 %	Soil Formation
0.3 billion	Ferns, cycads		
65 million	Dinosaurs perished		
10,000	Homo sapience		
6,000	Start of Agriculture		Soil degradation

Fossil of Stromatolite

Initial photo-synthetic bacteria, released oxygen

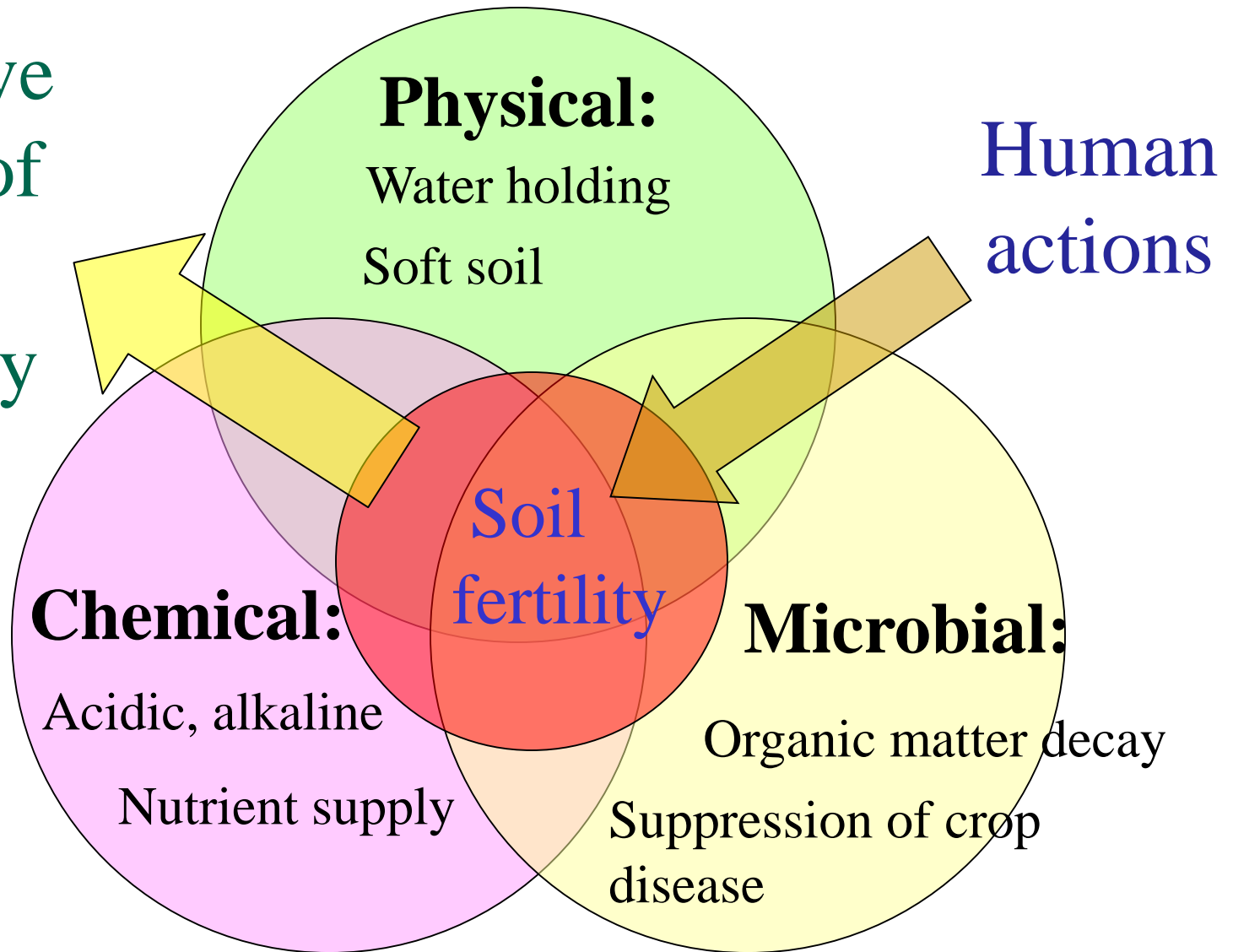


Bridging of anaerobic world to aerobic world



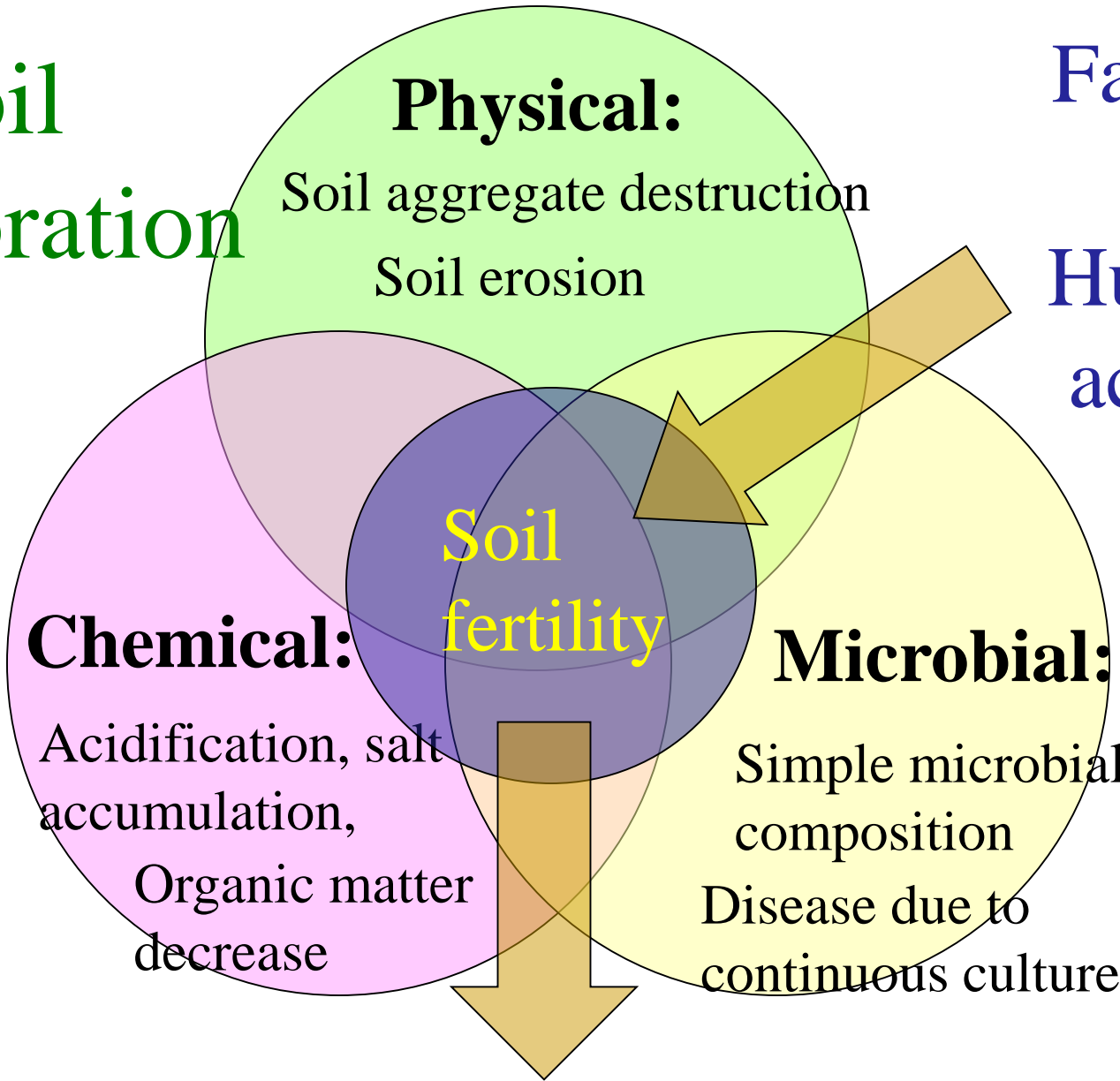
Composing factors of soil

Improve
ment of
soil
fertility



Action of farmers on Soils

Soil deterioration



Failure
in
Human
action

Decrease in soil fertility

What is Soil Fertility?

State I: Natural fertility

State II: Fertility realized by establishing the environmental condition so that crops can absorb nutrients smoothly

State III: Fertility realized by securing the quantity and quality of necessary nutrients to support the crop production

(Proposed by K. Kikuchi)

Human action

Functions of Soils

- **Supply nutrients to plants, animals and human**
- **Support the growth of plant roots**
- **Decompose organic matter (Complete circulation)**
- **Hold water**
- **Adsorb harmful substances**
- **Provide amenity for human life**

Soil functions

Soils deliver ecosystem services that enable life on Earth



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fao.org/soils-2015

Functions of soils (FAO)

- Soil provides various services on ecosystem, and enables the continuance of life on earth.

Functions of soils (1)

- Provide foods, fibers, and fuels.
- Sequestration of carbon (Stabilization)
- Purification of water and remediation of soil pollutants.
- Climate adjustment
- Nutrient circulation
- Habitat for soil lives

Functions of soils (2)

- Adjustment of flooding
- Supply medical and genetic resources
- Basics of infra-structure for human life
- Supply construction materials
- Preservation of human cultural heritage

Cause of soil degradation

- Forest clearing (Land establishment ▪ Slash and burn)
- Over-grazing
- Plowing ▪ Agricultural practices
- Soil erosion (water ▪ air)
- Desertification (Changes in climate, temperature and moisture regimes)
- Salt accumulation
- Human caused pollution (Industrial ▪ Agricultural ▪ Accidents)

Cause of soil degradation (% of degrading land)

area	Forest clearing	Fuel woods cutting	Over grazing	Agriculture	Industry
Europe	38	-	23	29	9
Africa	14	13	49	24	-
N. America	4	-	30	66	-
C. America	22	18	15	45	-
S. America	41	? 5	28	26	-
Asia	40	? 6	26	27	-
Oceania	12	-	80	8	-
World	30	7	35	28	1

Source: World Resources Institute, 1990. & L R Oldeman et al, Wageningen, Holland, 1990.

How about in Japan?

Soil degradation (Physical processes)

- Destruction of soil aggregates
- Destruction of soil structure
- Soil hardening
- Moisture and temperature regime deterioration
- Formation of soil coating (Crust)
- Kneading of soil (Slaking)
- Drying and wetting of soil
- Soil erosion
- Inferior soil aeration

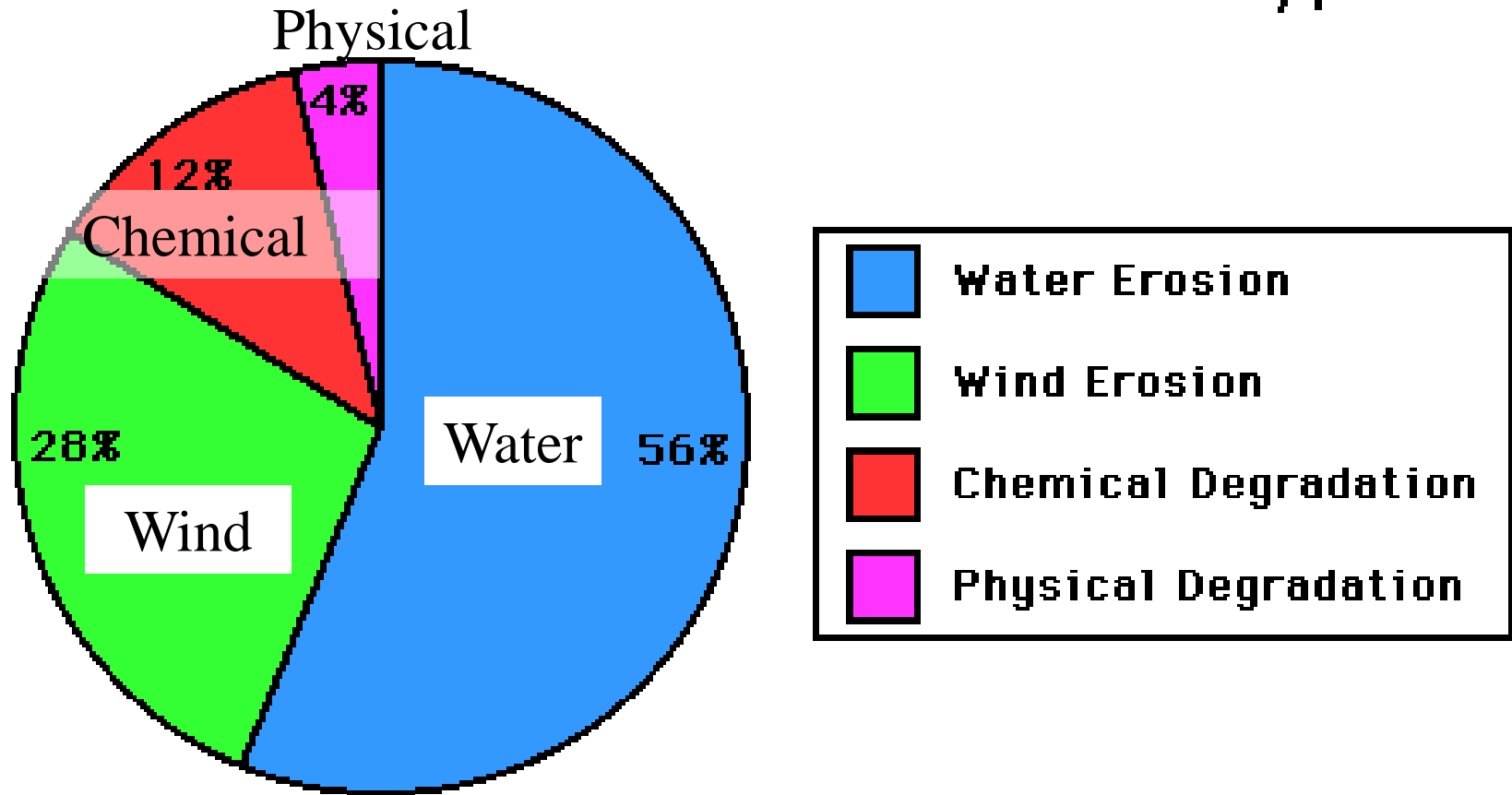
Soil degradation (Chemical processes)

- Leaching and biased balance of nutrients
- Acidification
- Decrease in soil fertility
- Eutrophication of aquatic area on lands
- Salinization
- Alkalization
- Laterite formation (Red soil weathering)
- Radio active pollution ^{137}Cs , ^{131}I , ^{239}Pu

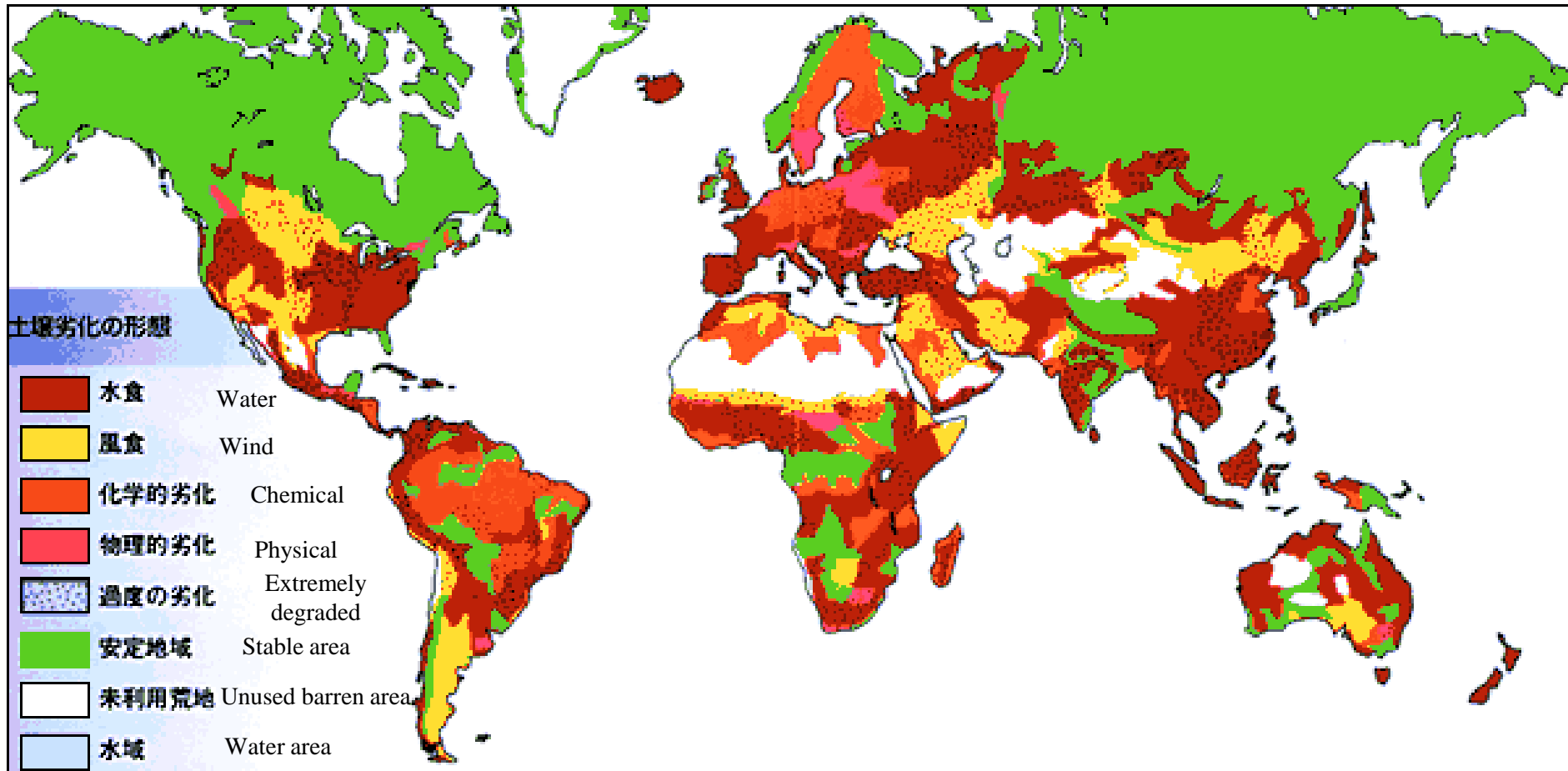
Soil degradation (Microbical processes)

- Exhaustion of soil organic matter
- Decrease in soil microbial biomass
- Simplification in microbial composition
- Decrease in soil biological activity
- Emission of green house gasses (CO_2 , CH_4 , N_2O)
- Decrease in bio-diversity
- Occurrence of soil born crop disease

World-Wide Soil Degradation Mechanisms for all Land-Use Types



Human caused soil degradation



FAO

How to prevent soil degradation

- Prevent wind and water erosion
 - Refrain from the agricultural land unplanted
 - Leveling of agricultural land
 - Plant wind break trees, Contour culture
 - Crop rotation
 - No-till farming, less tillage farming
 - Suppression of soil organic matter decomposition
 - Application of compost, cultivation of green manure and incorporation
- Activation of soil biota.

Merits of agriculture on environment

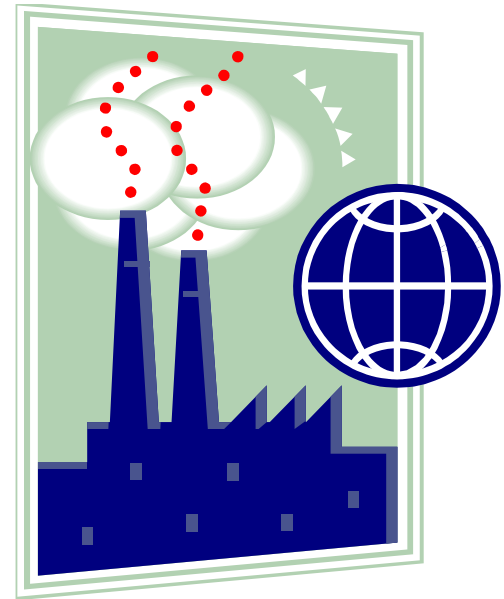
- Water holding and storage, prevent flooding (especially paddy land)
- Organic matter decomposition (Important function for nutrient cycling)
- Photosynthesis (Absorption of CO₂ and formation of Oxygen)
- Cover the soil surface (Prevent erosion)
- Supply beautiful landscape
- Background of human society

Negative effects of agriculture on the environment

- Flowing out of soils, turbid river water
- Soil dust in air (wind erosion)
- Leaching of nutrients (N, P, K) → Eutrophication of river and lake water
- Pollution by excess pesticides
- Bad smell (during the application of slurry and manure)
- Emission of greenhouse gasses (CO_2 , CH_4 , N_2O)
- Decrease in habitats for wild animals
- Decrease in natural environments (Forest, wetland)

Environmental Capacity

- Maximum load of pollutants by the environment (soil, water, and air) without causing negative effects to human and other lives.



Environmental capacity of soils

Organic matter: ca. **50 tons/ha**

Nitrogen: ca. **200 kg/ha**

**Standard for maximum application rate
of nitrogen fertilizers**

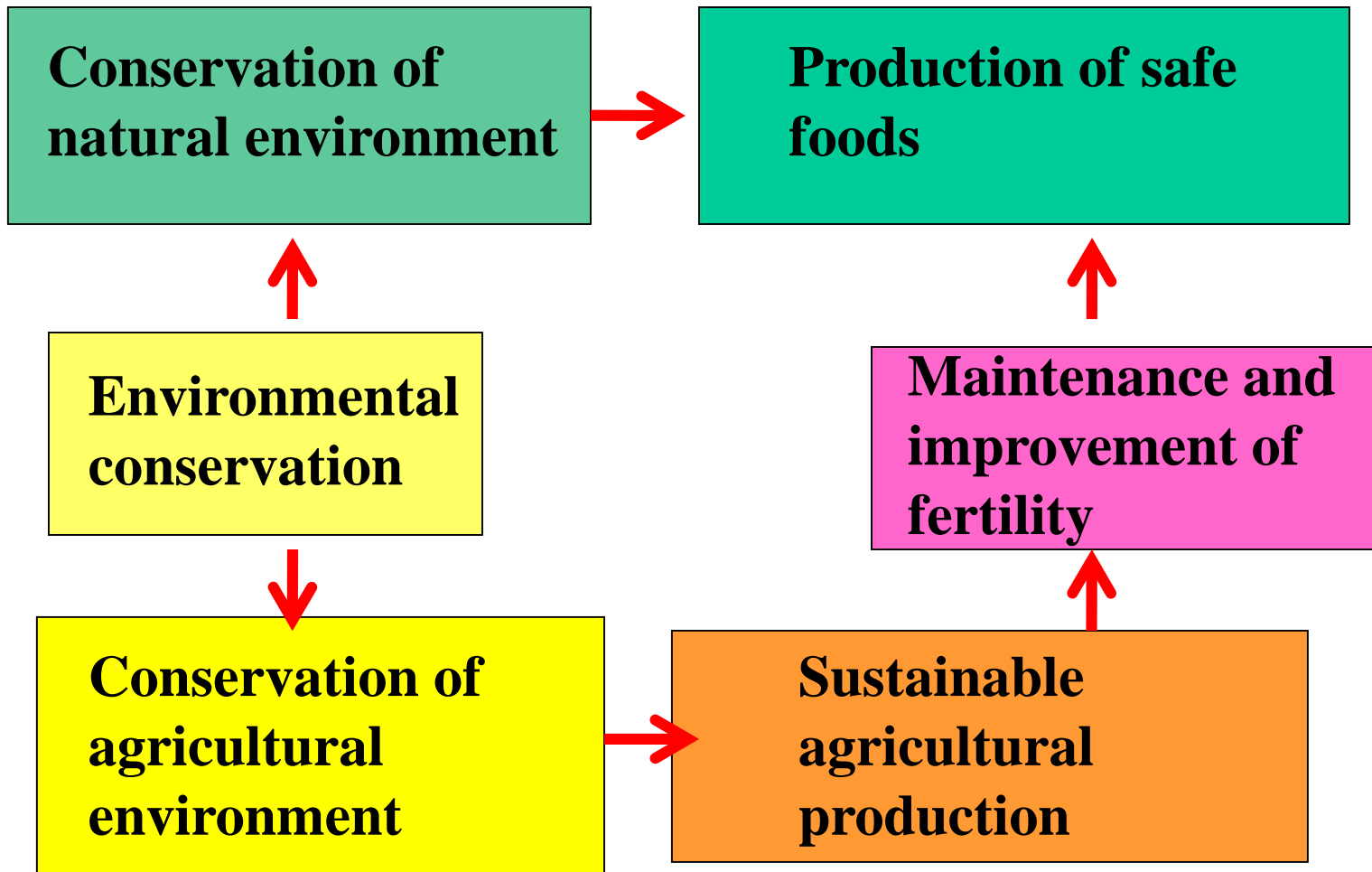
(In Europe, 140 kg N/ha is adopted.)

Carriers of environmental capacity

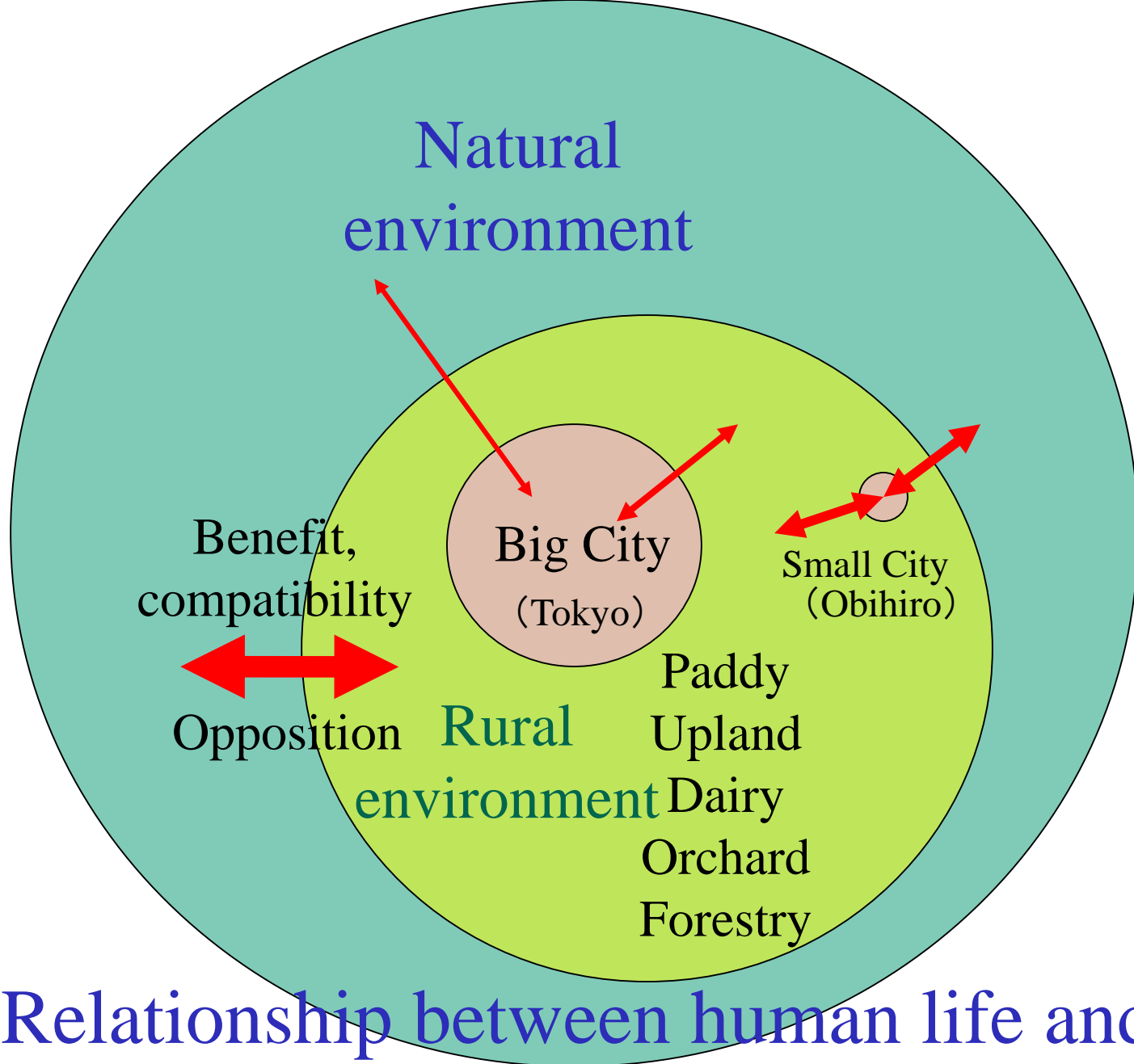
- **Clay minerals (Adsorption, ion exchange)**
(Crystalline clay minerals, allophane, gels of alumina and iron)
- **Soil organic matter (Adsorption, ion exchange)**
(Humic substances, applied organic matter)
- **Soil animals (Decomposition)**
(Fallen leaves, harvest rests, animal remains, feces and urine, organic wastes, residual pesticides)
- **Plants (Absorption)**
(Green manure, phyto-remediation)

Soils and soil lives are

- Contributing to the purification of environments.
- If the lives in soils are lost, circulation of materials will stop, and the background for all the creature will be lost.
- Human should treat the soil and the lives in soils carefully.



Purpose of Agricultural technology in harmony with environment



Relationship between human life and natural/rural environment

Soil is living

- Soil, like living things, is born, grows, and die.
- Human is benefitted from the soil only during the limited period of its process from the birth to its death.
- Misuse of soils by human may hasten the death of soils.

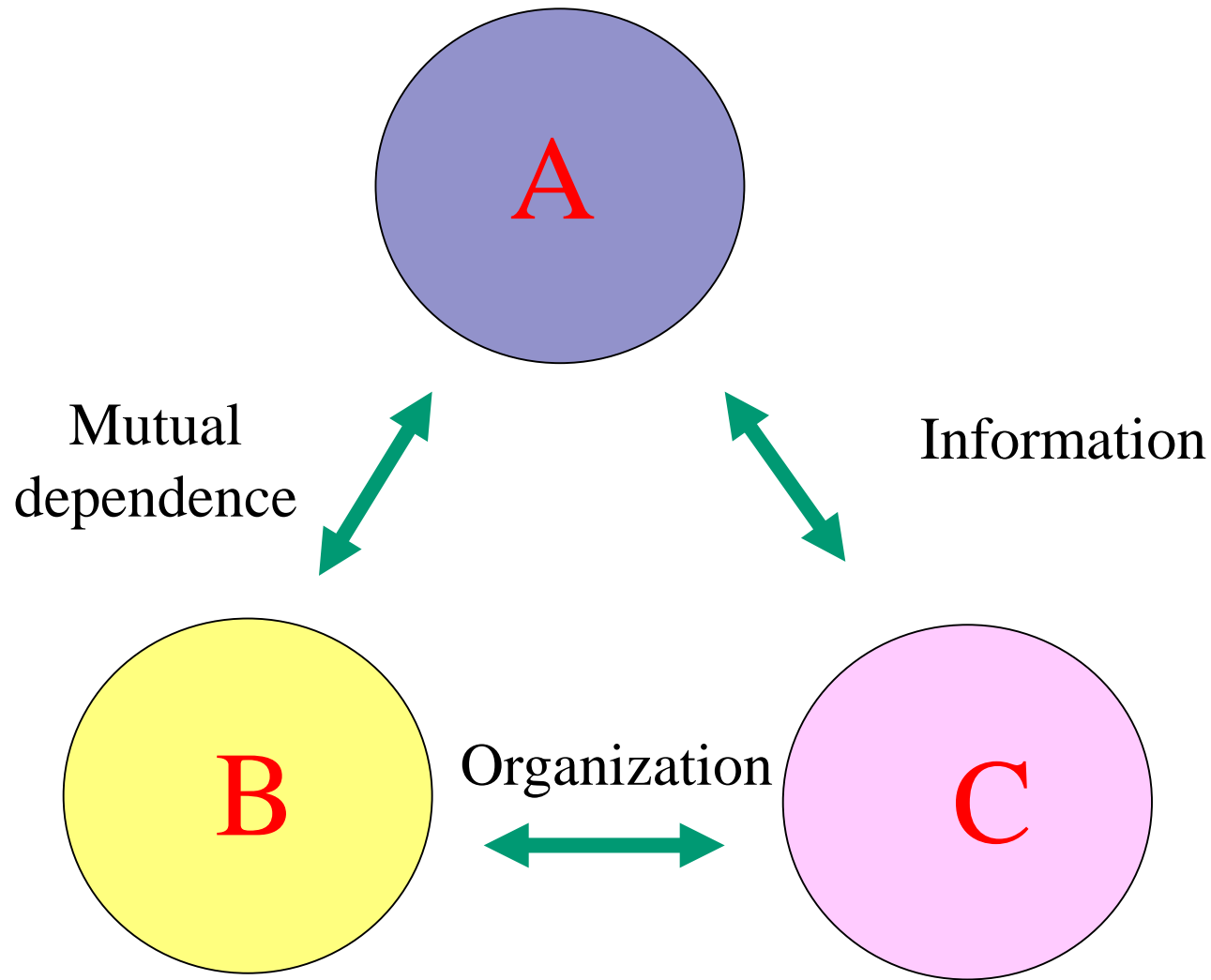
Creature lives by soil, while soil lives also by creatures.

- Soil exists on the very delicate balance of ecosystem.
- Therefore, soil is a very fragile (vulnerable) material.
- Conservation of soil is performed by the conservation of whole ecosystem.

Human can not but use the soil.

When using soils, human should follow the mechanism of natural ecosystem, and treat it tenderly.

- ⇒ Recycle organic matter into the farm land.
- ⇒ Harmony between forest and farmland.
- ⇒ Harmony between cultivation and animal husbandry.
- ⇒ Adopt the principle of plant succession by crop rotation and green manure cultivation.
- ⇒ Use and preserve various genes.



Factors A, B, C acquire new functions by establishing mutual relationships.

By establishing mutual relationships between
the factors,

- **The decrease in entropy and**
- **The creation of a new system** are brought about.
- Activities of living things, establishment of ecosystem, production activities, civilizations, and cultures all accompany the decrease in entropy.

It seems to be inconformity with the principle
of the increasing entropy.

Agricultural Ecosystem

- The relationships between the factors selected by human (the decrease in entropy).
- The denial and destruction between the other factors (the increase in entropy)
- While increasing the entropy in the surrounding environment, only the entropy in the agricultural ecosystem is decreased.

(Common tendency in the production activity by human)

Natural Ecosystem

- The relationships between infinite factors.
- By making the total relationship diverse and complex, the total system will be stabilized.
- The system will evolve for the decrease of entropy as a whole.

This is the keyword for
sustainability.

Both agriculture and soils ...

Can be led to their sustainability, wholesomeness, and stability, by making use of their complexity and diversity.

The rationalization and simplification only in their appearance are brought by sacrificing the sustainability, wholesomeness, and stability in the long run.

Soil and Civilization

Soil is the most important
environmental factor
breeding the civilization.

Local names for soils in Japan

- Masatsuchi
 - Matsuchi
 - Kuroboku
 - Onji
 - Shirasu
 - Boratsuchi
 - Kanuma-tsuchi
- Various places
- Volcanic ash and pumice
- Don-don heiya
 - Tokachi bozu
 - Bake tsuchi
 - Shiro-bane
 - Sabatsuchi
 - Goro-tsuchi
 - Sukumo peat
- Hokkaido
- Aichi

Local site names in Ainu language related to soils

Hiroo : Toyoibetsu (soil river)

Toyokoro : Toitokki, Toh-Etoku (The place where marsh ends)

Shakotan, Tokoro : Chietoi-nai (edible soil stream)

Honbetsu : Chietoi (Edible soil)

Urahoru : Chietoi ushi (the place of edible soil)

Kameda : Chietoibetsu (Edible soil river)

Urakawa : Retara toi (white soil)

Shizunai : Toibetsu (soil river)

Rikubetsu : Yukuepira (The cliff where deer eats soil)

Four patterns from the birth to the death of soils

- Humid cool climate type
- Humid temperate climate type
- Dry climate type
- Glacial climate type

Fujiwara (1991): Soil and the Japanese ancient culture

The relationship between human and soil

- Human is benefitted from the soil only during the limited period of its process from the birth to its death.
- The relationships can be observed between the civilization or culture and the soils in various places in the world, for example
- Slash and burn, and rice cultivation culture in Asia.
- Hunting culture in Europe.
- Oasis culture in the desert.

Soil formation under humid cool climate

- Podzol soil weathering
- Occur in the cool and boreal conifer forest vegetation band.
- Silicate remains and accumulates in soil.
- Soil bases, oxidized iron, oxidized aluminum, and organic matter are leached and accumulate in the sub soil layer.
- Soil becomes extremely acidic.



Ferric Podzol:

(Iron podzol)

Other Podzols in which the ratio of percentage of free iron to percentage of carbon is 6 or more in all subhorizons of the B horizon

No. 47,
Ferric Podzol,
Ferrod,
in Vindeln, Sweden

Soil formation under humid temperate climate

- Latosol weathering
- Weathering under high temperature and heavy rain condition
- Silicate and base are both leached.
- Oxidized iron and aluminum remain and accumulate.
- Soil is acidified.

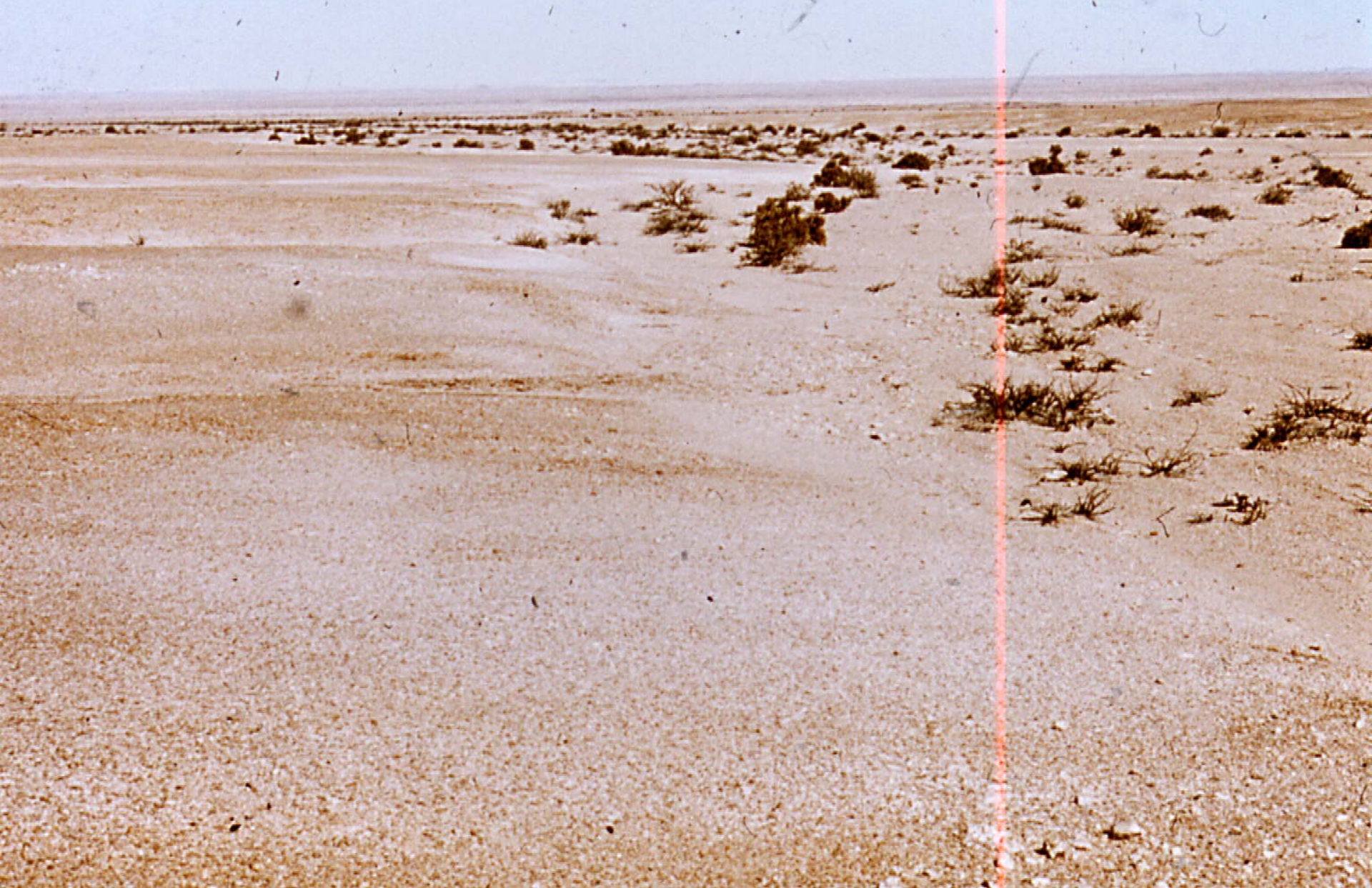


Deeply weathered
iron alumina soil

No. 61,
Deep weathering
down to 18 m
in Orthic Ferralsol site

Soil formation under dry climate

- Desert soil weathering
- Under high temperature and little rain condition
- Mechanical weathering prevails.
- Soil base and salts remain and accumulate.
- Alkaline soil formation



No.20, Gypsic Yermosol, Petrogypsic Gypsiorthid,
in Namib desert



No. 19, Gypsic Yermosol, Petrogypsic Gypsiorthid,
in Namib desert

YERMOSOLS (Y): Other soils having a very weak ochric
A horizon and an aridic moisture regime

Glacial climate

- Mechanical destruction of rocks by ice and snow.



Soil and culture

- Podzol soil culture
- Brown forest soil and volcanic ash soil culture, slash and burn
- Red yellow soil culture: Slash and burn culture transferred through the east china sea (Ever green forest culture)
- Latosol culture
- Coral and lime stone soil culture
- Grassland soil culture
- Oasis soil culture
- Yellow soil culture in China
- Paddy soil culture in Japan

Stone · Sand · Mud

Bases of different civilizations in the
world

Kenichi Matsumoto

Civilizations of sand, stone, and mud
(PHP books)

Civilization of mud (Shincho books)

Civilization and Culture

- **Civilization**

The mode of human life accompanying the formation of city, citizen, and nation.

- **Culture** (common to agriculture)

Mental activity of human in a high dimension depending on the history of folks and climate.

Both civilization and culture

Are not based on the inherent nature of the human, but depend on the education state, knowledge, moral, and the ability of literacy acquired in the society.

Civilizations of sand, stone, and mud

- **Stone** : Europe (Christianity)
- **Sand** : Desert area in the far east
(Islam, Civilization of oasis and trading)
- **Mud** : Asia
(Buddhism, Hinduism, Polytheism,
Civilization of paddy agriculture)

Civilization on Sand

- Civilization born on the barren land.
- Trades in oasis
- Communication and contract are important
- Network is strong
- Monotheism

The remain of ancient Roman city in Lybia



Civilization on stone

- Civilization evolved on the basal rock remained by glacial movement.
- Male supremacy (The god is male)
- Large area is necessary for animal grazing.
- Always seek for new lands.
- The force expanding to outside
(The same tendency in Spain, England, and America)

The view of Aran Island



Rock is crushed, and see weeds are incorporated to make field soil for growing potato.

Civilization on mud

- Evolved in a fertile monsoon area.
- Abundant living activity is bred by the mud.
- Polytheism (Buddhism, Hinduism, Shintoism)
- The female line society
- Equality between man and woman
- Ability turning inward

Civilization on mud (2)

- This civilization is most filled with vital energy.
- Earthen ware was first invented in this civilization.
- Mud is also used for the construction material for houses.
- Muddy land has a very high producing capacity, and can support large number of population.



Rice terrace in Yaotsu,
Gifu prefecture



Paddy field in Khon Kaen, Thailand

Reclaimed paddy field in Hachiro lake in Akita



What will be the future of soils in modern agriculture ?

- Will the conservation of soils be respected in the international competition and seeking for the profit ?
- Can the agriculture requiring large labor power though it may be soil friendly be competent with the performance oriented agriculture ?
- How far can we depend on pesticides, chemical fertilizers and genetically modified seeds ?

Thank you for your attention.