purpose of earth shaping systems is to coordinate the local hydrological cycle. Earth shaping systems can be used to spread water out, slow it down, and facilitate infiltration and storage. They also make more water available to the livestock. Hydrological changes may occur to the flow of water when the landscape is changed. When the shape of the earth is changed, it will influence water movement. Water usually moves over a landscape at 90 degrees to a contour lines (i.e., perpendicular to contour lines). It is important to note here that changing the shape of land can lead to unforeseen future problems. The general goal is to evenly distribute water across the landscape. Earthworks generally consist of two processes:

A. Digging (e.g., ponds, swale and berms, etc.).
B. Filling (e.g., errosion gullies).

2. **Account for architecture:** Architecture on, over, and within the landscape should be accounted for when re-shaping earth.
3. **Account for infrastructure and fences:** Infrastructure on, over, and within the landscape should be accounted for. Fencing can have a significant impact on a landscape; it can control sound, control animals, facilitate animal forage and stream restoration, and help to control erosion.
4. **Account for transportation:** Transportation through the landscape should be accounted for when re-shaping earth. It is important to account for transportation roads when earth shaping. Roads can either be expensive to maintain, or they can be features that catch and move water passively from one place to another.
5. **Account for fires (an other inclement events):** In most locations it is important to consider fire mitigation techniques when re-shaping the landscape. Fire breaks can be composed of gaps in shrub and canopy vegetation, or they can be composed of fire-resistant woody crops.
6. **Account for human and machine access:** Ensure to design the landscape so human and/or automated machines can harvest nuts and fruits (etc.) between trees and/or within alleys (if such are to be used).
   A. This means considering the usage of automated harvesting machines in concern to plant placement.
   B. This means considering the application of earthworks in concern to how they will affect harvesting machines' and humans' ability to do their job.

5.3.1 Hydrological landscape modification.

A.k.a., Landscape modification for optimized site hydrology and production capacity (a.k.a., landscape water flows, storage, drainage, and irrigation)

All agricultural land needs a source of water. The limited water resources of land can be made better use of by first understanding the way rainwater runs across a slope, and then reshaping the land to control the water flow: both where it goes and the speed of flow. Land reshaping can also be used to collect excess water and direct it off the property, or into storage areas where it can be used during dry seasons. Changing the landscape will change the pattern of water flow. When water flows fast over a hard soil it does not soak in to any great degree, which can cause erosion. When water flows slower, more water will soak (infiltrate) into the soil and the potential for erosion will be reduced. Changes to the land structure can spread out, capture, and slow the movement of water over and through a landscape.

Water on and within the landscape can be:

1. **Held, retained and stored** (e.g., in ponds, lakes, pond networks).
2. **Captured and infiltrated** (e.g., swale and berm structure). Swales and berms facilitate the stoppage, spreading (diversion), and infiltration of water.
3. **Channelled** via conduits (e.g., swale and berm, or piping) to be:
   A. Used elsewhere (e.g., livestock watering, human use, or irrigation).
   B. Infiltrated.
   C. Retained on the landscape.
   D. Stored off the landscape.
4. **Evapotranspired** - evapotranspiration (ET) is water that leaves the land surface and goes back to the atmosphere as water vapor through plant transpiration and surface evaporation.

The following are the types of modification that can be made to a landscape to change the water flows and dynamics therein:

1. **Filling**
   A. Filling is the process of moving the excavated material or additional earth material to a work location to achieve the desired topography. The most common filling on a new landscape to remove erosion gullies.
2. **Digging ditches/trenches (excavating lines in the landscape):**
   A. **Ditches (a.k.a., trenches)** - any excavated channel in the ground designed to change the flow of water, including the movement of water from one location to another and the infiltration of water. Note that the most common use of

the term, ditch, refers to a channel that drains water away from an area quickly, thus limiting infiltration. Ditches can be used for irrigation and drainage. Ditches on contours will capture and infiltrate water.

B. **Swale (trench)** - a long, level or slopped excavation along the landscape intended to capture surface water runoff (from rain, roof, road runoff, tank overflow, diversion drains, etc.) and then infiltrate and/or move it.

1. **Absorption swales (a.k.a., absorption trench, water harvesting ditch, keyline swale, swale and berm, trench-berm, keyline canal, etc.)** - An absorption swale (sometimes just, swale) is a type of ditch that follows the contour of a terrain and acts as a drain; they are simple canals or ditches that are contoured with the landscape (i.e., made at the same height). A swale is the creation of long, level hollows, furrows or other excavations (which may also include barriers, such as berms) created across a slope. Swales and berms can be created via a number of methods, including: shovel and hoe, bulldozer, or excavator. A swale is an uncompacted ditch, dug on or slightly off contour, to catch and infiltrate water and prevent runoff. As a swale infiltrates water deeper and deeper, tree roots follow the water downward. Swales are used to intercept overland water flow and then hold it for long enough to let it slowly infiltrate into the soil. This technique improves subsoil water storage. When it rains, water will accumulate in the swale and slowly drain into the soil. When the rainfall rate exceeds the soil infiltration rate, water sheets on the surface of the soil and begins to flow downhill. As this sheet of water encounters a swale, it collects in the swale and stops flowing. This gives the water more residence time in the landscape and allows the water to soak in. Swale formation is the process of reshaping the land on or off contour to collect/harvest rainwater. Swales are the most convenient way to store water in presence of a slope, on and in the slope. Without the swale, the rainwater will flow downhill, and with strong rain, it will usually remove the top soil and cause erosion. Swales can prevent water from running and eroding top soil. The primary purpose of a swale is to slow and sink the water into the landscape, which also allows for passive irrigation of crops/forage. A swale is placed "on contour" (i.e., level) so water shouldn't generally flow in (Read: within) it. However, the spillway of a swale can feed into a pond, rerouting runoff without having to have the "swale" falling off contour. Further, permeable pipes (e.g., french drains) can be placed in the swale at desired heights to drain the swale into a pond or elsewhere. In some cases, like in the tropics, mulching material (e.g., dry grass, bark or some other coarse medium) is placed on the swale to reduce evaporation and also to act as a sponge. Some plants that may be placed on the berm or near the swale may not like damp environments, so mulching material used for the absorption of water will reduce moisture level in surrounding soil. There are concerns with producing swale-type structures on the landscape. Swales and other permanent water features that will concentrate water into a very small part of the landscape for a long time. Swales under some conditions could lead to landslides. As a technique, swales generally work best in more arid climates.
2. **Spreader swales (a.k.a., off-contour swales)** - A spreader swale takes water away from wet spots slowly. Spreader swales move water downhill slowly, typically at a 1 percent slope (Read: .3 meters elevation drop over 30 meters distance, which approximately a 1% slope or 1 foot drop to 100 foot distance). This is the degree of slope at which water will just barely begin to move. Thus, unlike traditional ditches (which move water quickly away from an area), spreader swales intentionally move the water slowly across the landscape allowing it more time to soak in.
3. **On-contour swales** - on contour swales stay at the same elevation and are used for retention and infiltration (because they are not slopped).
4. **Off-contour swales** - off contour swales are for infiltration and diversion, because they include a slope, and hence, channel water somewhere.
5. **Collector swales** - A collector swale gathers water from a large area in order to create a surface pond.
6. **Fish scale swale and berm (fishscale swale and berm)** - These are not traditional contour line following swales. These swales are shaped like a "V", with the downward part of the V facing down the slop. They look a little like boomerangs. Often, the line of the "V"

shape forms the bern and a small v shaped swale is created uphill, inside the "V" shape. The inner side of the "V" shape is the swale that collects water for infiltration.

7. **Swale and berm** (usage for excavated soil) - The soil acquired from excavating the swale can be placed on the downward side and serve as a berm. A berm combined with a swale will help reduce the likelihood of downward erosion. The berm will also keep the moisture level in the swale higher, as well as in the berm itself. A swale-berm is a water harvesting ditch with a soft earthen mound that is located immediately downslope from it. For some sites it is necessary to design an accurately measured series of swales and berms to capture rainfall and spread the water out evenly; instead, of allowing it to gathering together in waterways and valleys where is transported to unusable locations.
8. **Zig-zag swale** - a swale that snakes it's way down the hillside.
9. **Swale and dam** - Swales can be combined with dams.

C. **Spillway (overflow conduit)** - A spillway is structure in the landscape designed to control the release of water from a water body source. A spillway or overflow conduit may be present connected to a pond, so that water overflow of pond enters a proximal swale and berm structure to further infultrate and channel water.

3. **Digging holes type (excavating holes in the landscape):**

A. **Pocket ponds (a.k.a., vernal ponds, ephemeral ponds, small ponds)** - A pocket pond is used to capture overflow rainwater. These ponds are dug on the landscape to catch overflow rain. Pocket ponds can also be designed for stormwater treatment. These ponds are designed to hold water during large rain events and to make that water soak slowly into the soil. Pocket ponds are the "surge protection" for the swale system when a large rainfall event occurs. These small ponds are placed at the heads of valleys and at the ends of ridges to collect water. These ponds have several main purposes: to spread the water out and have it soak in more evenly, and for amphibians (which eat insect and act as insect control). This technique improves subsoil water storage. These are ponds that drain and eventually disappear and mimic ecological pond systems more commonly known as vernal pools or ephemeral ponds. Vernal ponds are wetlands that only exist for a period of a few weeks or months during and slightly after heavy rainfall (or, the area's rainiest season). These ponds can host a variety of insectivorous amphibians that provide pest control for the whole system. Note here that some pocket ponds do hold water throughout the season, even when that was not the original intention. Also, some ponds may be intentionally designed to do so throughout the driest months of the year.

B. **Ridge ponds** - when there is enough room on a ridge it is possible to place a ridge pond for the retention of water.

C. **Porous bottom ponds** - are designed to recharge aquifers. The idea is not to store surface water for any length of time but to get the water underground as quickly as possible.

D. **Keyline swales and pocket ponds** - With keyline swales designed to accept the excess water during large rain events water is captured and moved to the pocket ponds and overall toward the ridges. Pocket ponds are designed to fill up with this “surge” water and then slowly drain it into the keyline swales. A properly designed keyline swale and pocket pond system should be designed to capture and hold a region’s maximum rainfall event.

4. **Ridging/embanking (a.k.a., mound, berm) types:**

A. Mounds (berms) are earthen surfaces that rise above the terrain. There are many different type of mound constructions:

1. **Berm (a.k.a., mound)** - a berm is either, a temporary flat strip of land on a sloped landscape, or a raised bank (an artificial ridge or embankment), often adjacent to a water body. In the case of a swales, a berm is a low earthen wall adjacent to a ditch that can be used to help retain runoff in the designated swale area along the downhill side of the location. In general terminology, a berm is a mound or wall of earth or sand on a landscape. Berms help to keep water in swales and ponds.
2. Pure earth mounds - Mounds made of earth taken from somewhere else and deposited on another terrain, shaped into a line with a curved (mound-type) profile.
3. Hugel style mounds - Hügelkultur is a German word that means hill or mound. In Hugel style means no-dig raised beds constructed from decaying wood debris and other compostable biomass plant materials, which effectively creates a soil mound with logs and other

material inside. These mounds rise above the terrain. They hold moisture maximize surface volume.

5. **Terraces** - are step-like structures cut into the landscape. They reduce the slope gradient and length, facilitating the cultivation on steep slopes, and they increase the infiltration of water in areas with a moderate to low soil permeability, controlling the overland flow and velocity, with positive effects on agricultural activities. (Perlotto, 2018) Terraces reduce the downhill flow of water and control for soil erosion Terraces work best in climates with lots of precipitation and/or a steep slope, where as a trench and berm works in any climate.
6. **Subsoil explosion (a.k.a., subsoiling, keyline subsoiling, keyline pattern cultivation, subsoil ripping, yeoman plow, keyline plow, subsoil plowing, micro trenching, etc.)** - A keyline plow is a hook-type (knife-type) instrument pulled behind a tractor and creates micro-trenches in the landscape. The "shanks" separated some distance from one another are pulled through the soil by a tractor, and in doing so, the shanks breaks/releases the compaction of the soil in a "V" shape (i.e., releasing the compaction as the volumetric measure of the density of the soil (weight per volume). With the additionally created air-space (without any tilling), air-space becomes water space with the introduction of water. The tool used for keyline plowing is the "Yeoman's" plow, a subsoiler with very thin shanks. It cuts slices into the landscape that allow rain to evenly distribute and infiltrate into the soil. The non-inversion rigid time plow is pulled through the ground, which explodes the subsoil, thus allowing air and water to infiltrate into previously compacted soil. Before this tool is used, go around the land and take samples with a penetrometer (a tool pushed into the ground that measures the compaction power as well as the depth pushed into the ground for reading the compaction of the ground). The subsoiler hook cuts a slot in the ground and slightly lifts the soil on either side of it, which shatters compacted layers and reduces their psi. Tight soil can be loosened by the mechanical action of a subsoiler. The keyline plow is meant to penetrate the subsoil, to a depth of ~2" below existing rooting depth without inverting the soil. The plow is dragged in a pattern uses keyline geometry; which effectively creates micro ditches across the landscape, which acts as a micro-water management storage ditch strategy, holding more water on ridges and landscapes. The effect is to loosen compacted soil and open up micro-water harvesting & diversion ditches across the landscape. In some pastures, it is possible to increase the rooting depth of forage plants by breaking up hardpan and allowing root access into these micro-furrows. The roots of many plants, particularly grass plants, have a challenging time penetrating soil compacted at 300psi and higher. These ploughs can be used over and over again each year to reduce the compaction of the soil at lower and lower depths. This system creates soil that is capable of infiltration at a rate greater than before. This technique also allows grass and other plants to create deeper roots. This technique improves subsoil water storage. This technique will not work when there are rocks present in the soil or on the land. This technique requires a special plow and a tractor. Generally, keyline plowing is done once a year around springtime. This instrument can be pulled over the entire pasture, or just the alleys.

   A. Types of keyline plowing:
      1. Keyline plowing can be done on-contour throughout the landscape (where appropriate, in place of a swale-berm structure. The goal is to find the first keypoint, and they plow on-contour, every parallel contour downward. With rows of on-contour plowing parallel down the slope every meter to couple meters apart (i.e., the vertical interval of plow lines are a meter or more). Keyline plowing like this over the landscape will make the pasture more bumpy to walk and tractor across. Plowing like this all across the landscape could have the effect of drying out the landscape more quickly (which, is not preferred).
      2. Keyline plowng can be done in-between swale and berms.
      3. Keyline plowing can be used to cut the roots of woody plants (in the rows) that are moving into the alleys and would otherwise begin taking nutrients away from the plants in the alleys.

   B. Notes on keyline plowing:
      1. Air can be introduced by various techniques including using a subsoiler, disc harrow, cultivators and plows, and suitable seedbeds can be created with disc harrows, tillers and spading machines.
      2. Be careful of steeply sloped terrain that may not be safe for tractor use.
      3. Poor timing of keyline plowing can op up soil to increased evaporation and could create compaction or tractor tire ruts.

7. **Dams** - are above ground water with a retaining wall to reduce and/or prevent the flow of liquid and materials due to gravity. The walls of dams can be made to collect erosion, inhibit the flow of water, and/or collect water. Dams open up the opportunity for hydroelectric power and aquaculture.
   A. **Filter dams (a.k.a., check-dams, gabions)** - slow the descent of the water while retaining organic material and sediment. These are usually made from logs from the local environment. If no trench berms are built in the watershed above, these get filled with sediment and become water storage vessels that slowly release water
8. **Installation [of pipes]**
   A. Pipes can be installed that will allow for drainage, livestock watering, or irrigation. Pipes can be gravity-fed or use a pump.
      1. **Diversion drains (e.g., french drain, perforated drain pipe, drain conduit, water channel)** - A diversion drain is "on a falling contour" sometimes with a fall of 1:300, so that water will flow in an intended direction.

5.3.1.1 Hydrological "keyline" landscaping (a.k.a., "keyline" system design, hydrological site design)

Hydrological "keyline" design is a landscaping earthworks terrain modification technique for maximizing the beneficial use of the water resources on a landscape. Here, the "word" keyline is essentially synonymous with "water flow". The "keyline" represents a specific topographic feature related to the natural flow of water on the landscape. Keyline systems use a variety of techniques to capture rainfall, slow the water as it moves over the landscape, spread the water outward toward the ridges where it is needed (and tend to be dryer) and can soak in, and store excess water in the soil, ponds, and tanks. By slowing down fallen rainwater and spreading it out, it will have an increased time in the landscape. This gives the rain time to soak in rather than run away. An exception to this would be sites that are pre-existing [true] wetlands (although, not if they were created by improper water management in the first place). The concept of "keyline" planning (a.k.a., hydological site planning is based on the natural topography of the land and its rainfall. Each land area has a "sweet spot" line representing a single, water-collecting swale, which impacts (or has the possibility of impacting) the water flow on a maximum number of hectares of that particular land with the least amount of earth shaping. On most properties this "sweet spot" will be located somewhere near the keyline of a slope. The "sweet spot" is an inflection point is at the place where the contour lines go from closer together on the convex slope to wider apart as the slope broadens and becomes more concave. It's called a "Keyline" because it's a contour line starting at the "Keypoint". Once the keylines are located, a laser level, transit or A-frame is used to accurately measure out where the water management swales will be located.

A contour map is essential in order to best understand the rise and fall, and flow of the land. The leading proponents of keyline design recommend the use of orthophoto maps (aerial photomaps which are available from keyline consultants) because of their increased contour detail.

"Keyline" design and planning was first by Yeoman's initial article, which included the following order of operations:

1. Water - calculation of key points and keylines in order to aid placement of dams and irrigation channels. Placement and size is decided by the contours and the surrounding suitability of flood irrigation land.
2. Roads (accessways) - Roads should not cut across contours as this interrupts water runoff flow. Generally, road placement should be along the top of ridge lines and elevated contours.
3. Trees - Trees are crucial to sloping land in stabilizing the soil, providing shelter from the elements and controlling erosion.
4. Buildings - Buildings are placed on considerations of comfort, aesthetic attributes and practicality.
5. Fences - fencing can be applied to correlate with the planned subdivision of the property based on its production requirements. Fencing should also be used to protect trees and dam access from damage by livestock. Fencing can protect from erosion. Fencing can control livestock movement and provide shade. Fences can be permanent or temporary.

Sometimes the "key" terminology is difficult to understand. Instead of the word "key", one could just say, "important water points". It is possible to make the language here more precise using the following terms to identify the primary elements of a hydrological terrain design (rather than the word "key"):

1. **Water source point (key point; keypoint pond)** - the point at which the water collects before traveling down some water channel.
2. **Water source channel (key line; swale & berm)** - the water channel extending off of a water source point ("key point").
3. **Ridge source ponds** - ponds on ridges, if sufficient space.

There are three basic principles when it comes to intentional water movement over the landscape:

1. Water may be directed to flow from the valleys to the ridges [by means of the water source channels, a.k.a., key lines].
2. When there is a water channel network with ponds, then water may also flow from the ridges to a water source point pond (keypoint pond).
3. In general, the slope of the water source channel (i.e., the slope of the swale and berm structure) should always be 1% (as in, 1 meter over 100 meters or 1 foot over 100 feet).

Keyline design and planning (a.k.a., hydrological design and planning) involves the following three concepts related to water and the way water flows on a landscape):

1. **Water source point ("keypoint" or "key point")** - every primary valley has a "keypoint". It is the point at which the primary valley gets suddenly steeper. The key point is the point on the contour map in a valley, where the lines bunch together and then stretch out. A pond is generally placed on the first largest spaced contour line after the lines bunch together. This is a common location for a dam, pond, or swale placement. A keypoint is a position located along the centerline at the base of the steepest part of a primary valley, where the concave becomes some kind of convex shape. Keypoints are mostly about the storage of water at particular points (elevations) on a landscape. The transition between a convex shape (hill) and a proceeding a concave or high- slope shape that ends the hill is where the keypoint may be located. Imagine a steep slope merging with a more gentle grade. Where steep meets shallow is the "keypoint". Actually, the "key point" itself is not the point of inflection where a slope goes from convex to concave, but rather is located just below this inflection point. The "key point" is the highest point where water will fill up in a valley if that valley is dammed. The keypoint is important in terms of collecting, storing, and transporting water. A dam placed above the keypoint will not collect nearly as much water as a dam placed below the keypoint. If a dam is placed below the keypoint, it will store much more water, because there is a larger volume of water present for it to store. In general, dams are placed below the keypoint. Functionally, the "keypoint" is the first place where it is practical to build a dam as far up a watershed as possible. Build the dam at higher elevation and you won't collect enough water (and engineering becomes painfully expensive). Build the dam lower and you will need a larger structure (which increases costs). Also: The lower in elevation you build a dam, the less "head" you have to work with = water pressure is lower and the amount of land that can be irrigated by gravity is greatly reduced. The water collected by the dam will reduce the water and moisture level on architectural structures below, and can also be directed via ditches or pipes for irrigation to crops/forage below.
2. **Water source channel (a.k.a., "keyline", "key line", swale/trench)** - a line that runs through a keypoint and extends to where the contours of the valley start to become the sides of the ridge. Keyline swales spread out rainwater. Keyline (key line) is not so much about storing water, but is more about water dynamics (i.e., what is the behavior of rain water after falling on the landscape). On a hill, the water will mostly travel down the steepest part, and hence, in certain landscapes, certain parts of a hill may get less water because they are not as steep. Keylines are trenches (swales), and are excavated to more equally distribute the water over the surface of the landscape. From the "key point" on the landscape, a contour line is drawn, and this contour line becomes the "key line" (keyline). Water flows, but also collects in the trench. Hence, due to keylines, there is a greater distribution of water on the part of the hill that is usually avoided by the flow of water. Without the keylines, less water will hydrate certain parts of a hill due to them having less of a slope than other parts.
   A. Depending on the following factors, the channels capture and move water on the landscape (e.g., keyline swales) have to be different sizes and different distances apart:
   B. The rainfall patterns of the area.
   C. The soil types.
   D. The infiltration rate (how fast the water soaks into the soil).
   E. The slope of the land.
   F. How big the area is that rain is being caught from.
3. **Keyline planning and cultivation rules (a.k.a., keyline cultivation patterns)** - The key idea behind ‘Keyline’ water management is to consciously slow, sink and spread rainwater by relieving compaction, opening up pore space in compacted soil and distributing excess water towards drier parts of the landscape. This has the effect of buffering the natural concentration of water towards valleys and reducing flooding. By maximizing the flow of water to drier ridges (using precise plow lines or mounds that fall slightly off contour), it is possible to infiltrate water across the broadest possible area. In this respect,

keyline strategies can be both a flood and drought mitigation strategy. The basic keyline cultivation rule is that cultivation on ridges (above the keylines) should be parallel to and above the contour lines, whereas cultivation below the keylines should also be parallel, but below the contour lines. This means that water runoff above the keylines is directed towards the more gradual slopes for slower dispersal into the soil, and below the keylines it will be directed towards the greater slope for quicker dispersal, and hence will not result in swampy and therefore possible saline conditions. The basic idea here is that you create trenches that extend from the sides of a hill (i.e., valley centers) toward ridge centers to feed and store water there also. However, each landscaped must be analyzed individually because in keyline design planning it is not strictly (or, always) true that the best action is to take water from a valley high in the landscape and move it slowly towards a ridge(s).

A. **Keyline layout versus contour layout planting** - keyline layout differs from contour planting in that rows remain equidistant from one another. In reality, landscape contours are always irregular and never equidistant. Keyline layout seeks to optimize land usage while still maintaining equal distance in cultivation rows so as to maximize density and efficiency. Contour layouts leave irregular shapes that are difficult to maintain.

5.3.2 Natural swales and berms

NOTE: *Whereas mounds (berms) rise above, swales dip below.*

Swale and berm structures can be made by human earthworks and sometimes by natural means. Sometimes swale and berms structures (non-keyline if course) are made by organisms naturally on the landscape. For example, a landscape where termites build homes above ground, which then once unoccupied dissolve into the ground and overtop grows grass. A landscape may have many of these grassy mounds all over the landscape forming a natural swale and berm type system. These swale and berm structures generally only support water infiltration and do not direct the way as a keyline design would.

5.3.3 Swale and berm design

A.k.a., Trench berm design.

The two primary purposes of a swale and berm system are to:

1. Facilitate infiltration of the water.
2. Move the water to where it is most needed.

There are several good practices when it comes to the application of swales:

1. Catchment area X maximum rainfall event ever recorded = "safest design" swale + pond volume.
   A. The capacity of the swale and outlet system must be able to intercept and disperse this catastrophic event volume to avoid system failure.
2. Swales in clay soils can be deper with steeper sides. This makes sense also, because ponds are often filled with a foot depth of clay all around that is tamped down by a back hoe machine, in order to hold water in.
3. Swales in sandy soils must be wider with gently sloping sides.
4. Safest design volume is influenced by measured water infiltration rate, saturation point, and soil type.

Additional water terrain "keyline" understandings include, but may not be limited to:

1. The main ridge line usually descends in elevation so that every primary ridge and primary valley shooting off from it is lower than the next.
2. Each of these primary valleys has a key point located within it and the different key points from valley to valley are in different spots.
3. Every equidistant line used for plowing, swales, tree belts, alleys, etc. above and below the key contour line runs parallel to the key contour line.
4. Running parallel to the key line will ensure that both the parallel lines above and below the key contour line will slope gradually off contour and carry water runoff from the higher valley points to the lower ridge points which would otherwise have water rush off them into the lower parts of the valley.
5. The slightly off contour parallel lines should be gradual at 1:100 or even 1:300 rise over run.

Risks of keyline and swale techniques include, but may not be limited to (i.e., there are a few important considerations to keep in mind when installing a swale):

1. During very heavy rainfall, swales can overflow. If flash floods are a possibility, and to avoid erosion – you should include a rock-lined spillway to a lower swale, drainage ditch or catchment dam.
2. Pools of water in the swales may result in mosquitoes in warmer climates, it is recommended to mulch in the swale to reduce standing water. Also, planting of water loving ground covers help to stabilise the soil and absorb excess water
3. Swales can be adapted to almost any environment but may not be appropriate for areas with a high

water table or on extremely steep slopes.

4. Swales are most suited for deep rooted perennial plant species, trees, bushes & nitrogen fixing ground covers where regular access for maintenance or harvesting is not required.
5. Swales have the potential to cause landslides in tropical volcanic highlands where thick soil and underlying non-porous volcanic rocks become oversaturated with water causing land sliding and flooding.
6. Rotting of plant roots is a possibility when there is excess water collection below the swale. Woody plants on the bank may be ok, but below the swale and on the berm itself, woody plants may develop rotting roots.
7. Small rock clustered areas with no top-soil on the landscape can be incorporated into the downward swale side of a swale-berm structure, which will make more effective use of the landscape.

5.3.3.1 Swale and berm construction

A.k.a., Trench berm construction.

In general, swales and berms are positioned on gently to moderately sloped land (0° and 20°). If the slope is steeper than this, then the risk for dam blowout from too much water buildup, overflow, and soil destabilization is high. Slopes steeper than 20° usually use terraces.

There is an optimal way to construct a swale and berm system given a particular landscape (Leigh, 2022):

1. Design planning considerations:
   - A. Ideal landscape - 15% of the ground surface covered in water.
     1. Ponds.
     2. Swales to transport water to the ponds.
   - B. Design the system of swales and ponds for water to move:
     1. By the longest path.
     2. Over the longest time.
     3. With the least amount of friction.
     4. "The farther you lead water, the more storage you have."
   - C. Placement
     1. Place first swale at the property's highest elevation possible.
     2. Typically 1.2 to 1.8 meters (4-6 feet) below highest points.
     3. Place swales and berms (or terraces) and ponds.
        - i. Decide distances.
   - D. Begin the plan by marking the level contours of the property. This will determine the pattern of the ponds and swales.
   - E. Spillways direct water flow from higher to lower storage features and prevent overflow.
2. Sizing:
   - A. Depends greatly on soil and climate.
     1. Wider and shallower in sandy soils.
     2. Narrower and deeper in clay soils.
     3. Up to 6 m (20 ft) wide in deserts.
   - B. Should allow for slow water movement.
     1. Often, the slower the better.
     2. Should be able to walk the speed of the flow.
   - C. Should be large enough to not blow out the spillways.
   - D. Width.
     1. Can be anywhere from wheelbarrow width to roadway width.
     2. Should not exceed crown spread of fringing trees.
   - E. Examples:
     1. Small, front yard size - 20 inches wide and 8 inches deep .
     2. Large, pasture size swales - 1.2 to 1.8 meters wide and .457 deepn (4-6 feet wide and 18 inches deep).
3. Spacing:
   - A. Swales typically hold moisture 30-40 feet down the slope.
   - B. Distance between swales can be 3-20 times the swale width depending on rainfall.
     1. Large swales can be spaced 12 feet apart with average rainfall exceeding 50 inches.
     2. Large swales should be spaced 60 feet apart with average rainfall less than 10 inches.
   - C. On slopes, use height of trees to judge distance between swales, where berms are level with the height of the treeline below.
4. Sloping:
   - A. In general, the slope of a swale and berm structure should be 1% (as in, 1 meter over 100 meters or 1 foot over 100 feet).
5. Construction:
   - A. Built on contour (i.e., they are level to allow even distribution of water).
   - B. Equipment:
     1. Firstly, depends on size and budget.
     2. Can be dug by hand with shovels.
     3. Tractor with turn plow, scrape blade, subsoiler, disc harrow.
     4. Backhoe or excavator.
   - C. Ground can be ripped first with subsoiler, for the planned width of swale and berm.
   - D. Often dug into the subsoil.
   - E. Material dug from the swale becomes the berm.
     1. Berms not compacted or sealed (unlike pond walls).

F. Swale floor can be sloped to encourage water drainage in a particular direction.
G. Can be constructed to be backflooded by ponds.
H. Spillways to direct overflow to another swale or pond in a series.
   1. Lower than berm height.
   2. Can be packed clay, rocks, grass, concrete, anything that won't wash out.

6. Planting:
   A. Berm planting
      1. Essential for the long term functioning of the swale.
      2. Seeded or planted on either side after an initial soaking of rain.
         i. Grasses for herbivorous grazing.
         ii. Perennial shrubs and bushes.
         iii. Trees.
            1. Some of the collected water is stored in trees.
            2. Planted in the berm or above the swale (not in the swale).
            3. Highly recommended in arid climates to shade and reduce evaporation.
            4. Roots increase absorption efficiency
            5. Leaf drop adds nutrients and organic matter to the swale.
   B. Swale planting:
      1. Since the topsoil is removed, the swale itself is not typically fertile.
         i. Soil can be left to accumulate organic matter.
         ii. May be planted with grass.
         iii. May be filled with mulch or gravel, or nothing.
7. Living Swales:
   A. Living swales are planted swales, not earthwork swales.
      1. Constructed on contour of dense, clump grasses.
      2. The grasses stop and retain overland water flow, similar to dug swales.
      3. Common in regions with shallow or rocky soils.
   B. Over time, earthwork swales will fill in with plant and runnoff debris, and the planted berms will create living swales.

5.3.4 Maintenance of swales and berms

Basic swale maintenance includes:

1. Inspect swale after storms to make sure that rainwater has drained and there is no erosion.
2. Remove sediment and debris from in and around the swale.
3. Inspect pea gravel diaphragm for clogging, and correct the problem (if applicable).
4. Re-plant grass if the original grass cover has not been successfully established.
5. Keep grass at the appropriate height.

Seasonal swale maintenance includes:

1. Rototill or cultivate the bottom of the swale does not drain down within 48 hours.
2. Remove sediment build up within the bottom of the swale.
3. Repair eroded areas (as needed).
4. To complement the swale's water harvesting abilities, couple them with annual subsoiling.

Risks of using swales incluide,

1. Do not construct a fence or structure within the swale.
2. Do not over-mow or mow shorter than 7.6cm.
3. Do not mow or allow animals to forage on swale after rain event.
4. Be careful storing material or debris in the swale.
5. Be careful filling a swale.

An example watershed coordination process is as follows:

1. Identify the contour lines.
2. Observe the land when it rains. Watch where the water comes from and where it goes. The harder it rains the more may be learned.
3. Area and rainfall will give you a good approximation of how much water you can collect from a slope (watershed) of known dimension.
4. Concentrate on one (1) watershed at a time.
5. Keyline plowing is for flat areas and gentle slopes. A Keyline "plow" is a specialized tillage instrument similar to a chisel plow or subsoiler. Note that keyline plowing can be done with a common chisel plows. All that is required is a toolbar with 3/4 inch wide knives 12 to 16 inches long spaced 2 feet apart. Very simple = not expensive.
   A. Plow along contour lines once yearly for the first 5 years. Thereafter, plow only as necessary to keep range land healthy. Subsoiling creates slits in the soil that channel air and water into the subsoil stimulating underground micro-organisms, reducing compaction to improve water absorption and downward root area, and overall, improving plant growth.
6. Wherever the watershed is large enough, build a dam to retain water for flood irrigation of pastures at lower elevations. Alternatively, it is possible to build pocket ponds ("tanks") with porous bottoms

designed to trap and store water temporarily until it can soak into the ground and recharge aquifer.

5.3.5 What can be done using swales and berms to produce food, fuel, and fiber in a pasture environment on a slope of up to and more than 50 degrees?

The landscape can be terrain modified to include a contour line swale and berm perennial culture with grazing plants in the alleys between swale and berm lines. Contour the elevated differential landscape with swale-berm lines. Here, the alleys between perennial plants are for forage for gazing animals, relative to what type of slope they can handle, with some grazing animals being more able to traverse steeper slopes than others. These swale and berm rows/lines of plants are spaced up and down the hills with grass for grazing animals in between. Here, the swale and berm lines are on contour; meaning, this type of swale keeps everything level, such that the path of the swale moves along the contour, or elevation curve, of a slope. Doing this means that the water absorbs evenly into the land below as opposed to flowing to the lower end of the swale.

The berm sits on the downhill side of the swale and is the perfect place to grow trees and deeper rooting plants. The deep roots will keep the berm stable, as well as suck up the moisture from below so that the newly hydrated soil doesn't become overly saturated.

Simply, plant trees in rows, and the second row offset in a diamond grid pattern, and place a small berm on the lower side of each planting. Thus, allowing for the tree berms to slow the water down, and retain it for a period, allowing it time to soak to the roots.

There may also be hedgerows with grazing alleys in between contouring the landscape (a.k.a., contour hedgerows). The distance between each successive swale and berm (or hedgerow) structure contouring the landscape will likely depend on the slope of the hill.

> **NOTE:** *Specific types of trees and other plants grow well on slopes and help reduce erosion and increase water retention.*

5.3.6 How to create a swale and berm structure

The creation of a swale and berm structure on the landscape requires:

1. Diagrammatic planning.
2. Laser levels can help find the contour lines of a property.
3. Digging equipment to excavate and move earth.
4. Planting of plants in alleys, berms, and swales (where appropriate).

5.3.7 Most common earthworks pattern

The most common earthworks pattern found on holistically cultivated land is:

1. Fence, alley, swale, fence, berm, tree, fence, alley, swale, fence, berm, tree, fence, alley.
   A. The fence before the berm is placed just as the berm starts so that animals do not walk on the berm.

5.3.8 Soil compaction

Soils can get compacted from machinery traffic and from animal traffic. If animals are out grazing when the soil is wet, compaction is even more likely. Compaction reduces the rate of water infiltration and also reduces the potential depth of roots. Compaction is likely to reduce pasture yields. A penetrometer is a tool pushed into the ground that measures the compaction power as well as the depth pushed into the ground for reading the compaction of the ground. Soil compaction will reduce water infiltration.

In the context of water bodies on the landscape, high soil compaction is desirable. Even more preferable is clay compaction to form a natural impermeable membrane. If soil/clay compaction isn't possible, then often textile membranes are placed onto the soil to help retain water in the basin.

5.4 Landscape modification using plants (plant agriculture)

READ: *Planted-landscape cultivation planning.*

The plant ecological sub-system must be planned. Forage and fodder should be diverse and support a resilient food supply for animals. Gives animals a more diverse and healthy diet that is not only nutritious, but potentially medicinal. In essence, the design of a diverse cultivation offers animals a habitat that might resemble their "original" experience grazing in the wild.

5.4.1 Identify the local biome and key plant species

A.k.a., Identify the plants, plant selection planning.

The following are the steps for designing a landscape based on the local biome:

1. **Identify the local biome** (Read: zoning and bioming). A biome is a region on planet Earth that has similar plants and animals, similar rainfall patterns, and relatively similar soil types. Biome are also defined by the successional pathway that occurs in that region. Identify the hardiness zone.
   A. The concept of a **biome** refers to an ecological nich, which is a position or role taken by an organism within its specific ecological environment. An nich may be defined in part

by what resources are available in a particular location. Or, it may be defined by what resources are there during a particular time of the day or season. Or, it may be defined by a particular successional phase.

2. **Find the key species that produce food by selecting first woody and long-lived plants, then select the other plants, for the biome.** Often, the trees, which exist in the biome the longest. The largest and most dominant species often set the rules for the site. In other words, plants that are there for the longest period of time (often, the woody plants, trees) change/color the site -- they chemically change it with their roots, leaves, etc. For example, an oak or beech tree planted site will only allow oak or beech tolerant species to live there. Plants that don't like oak soil, which is soil that an oak tree is growing in won't grow around an oak tree.
   A. Identify the available plants, selected for function in a given biome. Plants that are adapted to a specific set of environmental conditions are the most likely to be the best producers on that site. If it doesn't want to grow, let it die.
3. **Imitate the system (the biome)** and work with what grows best there.
4. For a perennial farm, **plant many seeds and select the plants that behave the best** for our intended purposes (i.e., cull the rest). Select genetics optimized for pest free and disease free with no significant human inputs whatsoever.

In concern to an ecological nich (a biome), resources include:

1. Food
2. Water
3. Shelter
4. Reproduction sites.
5. Etc.

5.4.2 Plant disease control

It is possible to use both plants and animals to control diseases in plants:

1. Using plants to control diseases in plants
   - In restoration-type agricultural systems, it is often optimal to choose known pest and disease resistant varieties of plants. Then, do not spray chemicals to kill pests and diseases, and cull weak genetics. Use sexual reproduction to breed pest and disease resistant food plants, instead of poison immune pests.
   - Use other plants under taller plants to act as catchers of disease organisms.
2. Using animals to control diseases in plants
   - Animals can be used as a plant disease control system. Animals can be used to break the lifecycle of diseases that effect plants. For instance, diseased leaves (infected leaves) fall to the ground and lie on the floor until the conditions are right appear for the disease organism to spread itself. Having animals (e.g., cattle) eat the leaves significantly reduces the potential for future infections and the spread of the disease causing organism. Also, by using the animals to prune the lowest hanging leaves, and raising the lowest branches to a higher height, the likelihood of potential diseases is further reduced.

5.4.3 Identify the succession of plants

Identify which plants should be placed on the landscape first, and which plants should be planted over time.

5.4.4 Identify the spatial (location) and temporal (time) layout of plants on the landscape

The design process involves spatial and temporal layout information. Each plant has an identifiable lifetime within which it has requirements for light and fertilization. Each plant's relationship amongst other nearby species ought to be considered, as well as its physical structure and the structure of its leaves. Each plant will fit somewhere in a three-dimensional model of plant stratification over a two-dimensional land area. For each plant, given its lifetime, it is necessary to account for the time it will take a plant to occupy its strata, at maturity, and its physical space.

It is generally best to select primarily perennial plants that work in that biome and will produce useful food (and/or useful materials), and then position those plants appropriately.

An example planting arrangement might include,

> *Daffodils at the base of the trees eliminate sod while repelling rodents and providing early spring nectar and pollen for bees and cutflowers. Iris between the trees also provide sod control while yielding cutflowers and tubers used by a skin-care products companies. Comfrey (large green leaves) is used by a medicinal herb company and accumulates potassium and calcium while providing overwintering habitat for predatory insects and substrate for morels. This collection of compatible plants is only a small part of the larger system which includes chestnut, grape, hazelnut, rugosa rose, Siberian pea and currants and pears, with seedless grapes. The pattern then repeats itself across the landscape.*

5.4.4.1 Example planting of disease resistant and non-resistant plants

Chestnut tree row planting can be provided as an example where disease resistant and non-resistant plants are planted to produce a harvest succession. Both the disease and non-disease resistant chestnut trees are planted at the same time in a row(s). The quick growing chestnuts will eventually get blight (a disease) and die. The blight acquiring chestnuts are inter-spaced with hybrid slowing growing chestnuts that are blight resistant, but take a lot longer to grow. The fast growing chestnuts will produce first, and will then be culled as soon as they acquire blight. The slow hybrid chestnuts begin producing later. Hence, there is a continuation of production. After the being culled, the leftover stump will be used to grow mushrooms. And, a new lower canopy of tress or shrub may be planted.

5.4.5 Identify the method of planting

Plants can be planted on a landscape using different approaches (i.e., methods/strategies) to spacing and positioning:

1. By geometric arrangement.
   A. Row (with layers) on-contour.
   B. Row (with layers) off-contour.
   C. Square-like zones, triangular-like zones, etc.
2. By coordinate planning - plants are planted in specified coordinate locations.
   A. Identify the standard spacing and heights for plantings.
   B. Every plant has a specific coordinate on the landscape right from the start. Good space planting occurs right from the beginning -- trees and other plants are planted in coordinate locations with correct distances between them. Trees are planted with the correct distance between one another [in a row like manner].
3. By STUN (strategic total utter neglect) planning - plants are planted closer to one another and seeds are randomly thrown (in their appropriate 2D zone/layer). This method involves the selective culling of species that are not thriving. This method involves planting many (of the same plant near one another) and culling the ones don't do well. The perspective is to let the plants sort themselves out and then remove the ones that aren't thriving and feed them to the remainder.

5.4.5.1 Row planting

Row planting is important, not only for erosion prevention on slope, but also for ease of harvesting, particularly mechanical harvesting of the row and of the crop between rows. Row planting also makes it easier to protect plants in the row from herbivores. It is easier to move and arrange fences where livestock are being used in the system.

A row might include the following perpendicular layers:

1. Perennial grass for grass eating animals, including cattle, sheep, goats, chickens and pigs.
2. Fence (only if required).
3. Shrub and cane fruit layer.
4. Fence (only if required)
5. Vertical Vines crawling up the trees.
6. Tree line.
   A. Short tree zone.
   B. Medium tree zone.
   C. Tall tree zone.

QUESTION: *How do you know which will be tall and which will be short. The general answer is, you don't have to -- plant them and they sort it out.*

5.4.5.2 Example of row planting with a continuous swale and berm

Water flows downhill and is redirected via a swale-berm structure to infiltrate, as well as continue to flow downhill just in front of the tree row/line (planted after the berm). At the end of the row of trees, the water is directed via a continued swale-berm to make a u-turn. The whole (or just part) of the swale and berm may be zig-zag fed, or not. After the u-turn, the water flows down (just in front of) another row going the other way. Shrubs and other smaller plants are planted on the swale side of the berm. In general, the trees are planted just after the berm.

5.4.5.3 Plant spacing

Proper plant spacing provides multiple benefits that contribute to healthy plants. Firstly, it reduces competition, allowing plants sufficient nutrients to thrive. It also provides better air circulation, and this reduces many fungal and bacterial diseases caused by excess moisture. It also reduces the spread of disease.

5.4.6 Identify plant harvest data

Important considerations for placing species along a harvest succession timeline would be:

1. Time until it reaches mature size. Identify the plant's lifetime.
2. Time until harvest. Identify when the plant will have a harvest.
3. Time until removal. Identify weak genetics or intentionally planned removals.
4. Time until pruning. Identify if the plant and/or environment requires additional cutting.
5. Time until flowering. Identify when the plant can be pollinated.

6. Time until fruiting. Identify when the flower will become a fruit and when the fruit will be ready for harvest.
7. Seasonal weather patterns. Identify weather conditions.
8. Plant coordination issues. Continuously monitor and observe the plants to ensure health.

5.4.7 Identify plant seeding data

I.e., Seed production data.

Important considerations for plant seeding would be:

1. Identify when and how plants go to seed.
2. Identify how seedings will impact the ecology.
3. Identify if seeds are to be harvested (collected).

5.4.8 Identify the location for each plant on the landscape in 3D space

A.k.a., Plant elevation categorization, plant stratification.

Once the plant species table has been created, the next step is to identify the exact location of each plant on the landscape (if not using the random seed dispersal technique). A map should be drawn that shows the approximate location of every plant. Here, it is important to determine how all ecological niches will be filled and the number of plants that will be required to be installed in the system.

1. Plant location planning will (generally) need to take into account the harvesting of plants, and the safety and health of the habitat teams (i.e., workers). For example, planting a pricker-filled raspberry bush directly beneath an apple tree may make human harvesting of the apples more dangerous, may also make the pigs less likely to forage for fallen apples. In the case of human harvesting the apples, the humans may get cut, and raspberries would be unnecessarily crushed. The gap between plants may need to be considered if there is heavy automated machinery that will done any of the harvesting.
2. Plant location planning may need to take into account the placement of "special" category plants, such as those that have spikes. For example, raspberries are normally planted along the outside edge of one row. This is because raspberries produce spikes along the stems, and if they were to be planted throughout the system, it would be unpleasant to harvest other crops, and to harvest biomass.
3. Plants of the same species may need to be planted specific distances apart. And therein, consideration needs to be given to growth and the volume of area that will be taken up by the mass of the plant and the canopy, over time.
4. Often times it is optimal to place woody-harvestable plants in places where their harvest is simplified for humans and other animals.
5. Some tree species that drop fruit represent a potential danger to those passing underneath them. For instance, trees with fruit that could drop on someone's head must be considered for maintenance and/or positioned in an area where fruit drops are unlikely to hurt pedestrians. These plants (e.g., durian) can positioned near the riparian areas of the watershed area as that is a location less frequently traversed (due to agroforestry preservation techniques to preserve the watershed).

It is possible to identify a three-dimensional plant layering over the whole of the landscape. It is possible to classify common plant types according to their stratified position on the landscape and their requirements for sun. There are distinct vertical elevation levels (layers) over any landscape (from tallest to shortest; a three-dimensional solar collector stratification model can be established):

1. **The emergent layer** - mature, exceptionally tall trees. These trees emerge above the general level of the forest.
2. **The canopy layer** - typically, the most photosynthetically active layer (in a forest). The upper most layer of tree foliage.
3. **The understory (sub-canopy)** - in a closed canopy forest, where the branches of the trees are almost touching, the understory is composed of trees of trees with varying degrees of shade tolerant trees. Some of these trees may take over as canopy trees and others not.
   A. A mixture of plants as an understory planting may including, for example:
      1. Clover to accumulate nitrogen.
      2. Diakon radish, root crops, squash
4. **The shrub/bush layer** - likely to be comprised of shade tolerant plants.
5. **The vine layer** - these vines usually climb trees.
6. **The ground layer (the forest floor, ground cover)** - these are the most shade tolerant plants. Many ephemeral plants are located here. Ephemeral plants are those that have a rapid life cycle, and grow and set seed in a few weeks or months.
7. **The underground/rhizosphere layer** - plants that live primarily underground.

Different plants have the ability to thrive in different light intensities. Optimal placement of plants depends on the species requirements for sun (in relation to hemispheric location), which involve the following two broad categories (i.e., in concern to light exposure, there is a range, a spectrum, of plant types from those that require a lot of sun to thrive and those that require very little):

1. **Sun loving plants** - plants that do well in full sun. In general, these plants are placed on the south (northern hemisphere) and north (southern hemisphere) side of slopes. What plants like sun on themselves throughout the day? These most often include trees and grasses (note that even sun loving plants, like grasses can be optimized with some shade throughout the day to reduce leaf temperature).
2. **Shade tolerant plants** - plants that do well in shaded conditions. In general, these plants are placed on the north (northern hemisphere) and south (southern hemisphere) side of slopes.

Analysis and planning will have to occur to design an any given 3D spatial cultivation location/position, throughout the day and the year. The following questions must be answered:

- What is the sun intensity and angle of radiance on a plant's position, throughout the day and throughout the year?

The common plant types included in a stratified solar collection model include (note that some species in each of these categories are sun-loving and others are shade tolerant):

1. Tall and medium stature trees.
2. Tall and short shrubs.
3. Canes (e.g., raspberries and blackberries).
4. Vines.
5. Herbaceous non-woody perennials.

> **NOTE:** *It is often possible to maximize photosynthesis by laying out tree rows from north to south.*

For example, a holistic land pasture may be laid out with rows of edible woody plants with alleys between each row. For example, a one-hectare field may be planted with 18 rows of edible woody plants with a 7 meter wide alley between each row (Shepard, 2013):

1. **Canopy layer A** - 10 of the 19 rows are planted with canopy trees (e.g., chestnuts) planted 3.6 meters apart within the row.
   A. Understory layer - Within the row, beneath each tree, plant a row of upright small sized deciduous shrubs or bushes (e.g., red currant) 0.6 meters apart.
   B. Vine layer - Within each row plant one vine (e.g., trellised grape vine) on each tree.
   C. Ground layer - often perennial grass, and other producing plants.
2. **Canopy layer B** - 8 of the 18 rows are planted with medium trees (e.g., apple) every 7.3 meters with another set of smaller trees or shrubs (e.g., hazelnut bushes) planted as an understory every 1.2 meters apart.
   A. Understory layer - Bushes (e.g., raspberry canes) are planted on the south (or north depending on hemisphere) side of the entire row every 0.6 meters apart.
   B. Vine layer - Within each row plant one vine (e.g., trellised grape vine) on each medium tree.
   C. Ground layer - often perennial grass, and other producing plants.

The above spatial arrangement would result in a total for each hectare of:

1. 172 canopy trees (e.g., chestnut trees).
2. 68 medium trees (e.g., apple trees).
3. 416 understory shrubs/bushes (e.g., hazelnut bushes).
4. 832 bushes (e.g., raspberry canes).
5. 1040 bushes (e.g., red currant bushes).
6. 120 vines (e.g., grape vines).
7. A ground layer covered by grass and other food produced for humans and livestock.
8. An underground layer where food is produced for humans and livestock.

A highly simplified example could be:

1. Canopy high layer of oak, chestnut or beech.
2. Understory of cherries, apples, Hawthorne, plum.
3. A shrub layer is hazelnuts.
4. Raspberries and black berries as a cane fruit.
5. Grape vine currents around trees, and gooseberries in the shade.
6. Forage for grazing animals on the ground layer.
7. Tubers for foraging animals below ground layer.

An important resource for selecting plants based on their stratified location is:

- One Community Global: Food forest [onecommunityglobal.org]. *Note that this source is highly incomplete in concern to plants for animal forage.*

5.4.9 Identify where plants can play a role in protection

Protective strips/rows of plants can be placed over the landscape in order to:

1. Act as a fence and security.
   A. Predator protective plantings.
2. Act as path protection from rain and erosion (when placed along both sides of the path).
3. Act as erosion prevention.
   A. Anti-erosion plantings are made from vegetation with a developed root system: willow, acacia, poplar, willow. Such landings should be provided on steep slopes, slopes, embankments, hills. Landings are made along horizontal lines.
4. Act as a wind break.
   A. Wind protective plantings.
5. Act as shade from the sun.
   A. Sun protective plantings.
6. Act as a privacy break (e.g., around personal dwellings or common-personally scheduled quiet access areas).
   A. Privacy protective plantings.
7. Act as sound protection (e.g., around a common access pool area where children may be screaming.
   A. Noise-protective plantings are created along streets and highways from trees and shrubs with a dense crown. A good noise-absorbing effect is given by landings stepped in height, i.e., lower ones closer to the noise source.

5.4.10 Example holistic landscape apple tree planting, comparing inputs as expenses to inputs as yields

The input agriculture system can create the next problem in the landscaped cultivation system. For example, apple trees generally do not like to have their roots in dense sod (i.e., dense grass). Conventional growers will use herbicide and organic growers will use mulch or tillage. Mulch, tillage, herbicide are all inputs (as expenses in time, labor, and/or materials). Whenever there are expenses, it is often possible to turn that expense into an output (or, profit in terms of the market). To reduce sod around an apple tree, for example, it is possible to plant comfrey, daffodils, and irises, which will out-compete the sod. The grasses will die around the tree, the daffodils will bloom 3 week before the apples do, so all the wild pollinators will already there (likely, the second generation of wild pollinators will already be there by the time apples bloom). Iris roots and comfrey greens can be harvested and sold, generally to a medicinal herb company. University of Madison research shows that the number one overwinting habitat for beneficial insects is underneath comfrey leaf debris, than compared to other plants. Another benefit of having daffodils at the base of the trees is that they are toxic to rodents, which reduces the likelihood of rodents nibbling the bark off the trees. Here, all yields are accomplishing work, instead of being expenses. Apple scab is one of the biggest fungal disease in apples, apple scab spores infect the leaves, the leaves fall to the ground, and the next spring, when a raindrop hits the leaf at the right temperature, the spore is released upward, hitting the lower foliage and then climbing up the tree. It is possible to have a natural pruning process for apple trees up to about four or five feet, using livestock. After the natural pruning, any leave that falls with apple scab, if a raindrop hits it, if it splashes up the live leaf height on the apple tree is too high up to become contaminated. Alternatively, agrochemical fungicides, which is an input-expense, could be sprayed to reduce the disease. Another natural method of scab control may be applied in the fall, after the apple tree leaves have fallen, move the cattle through to clear space for harvesting. Then pick the apples by grading and harvesting the fruit. While harvesting, throw all the "bad" fruit with insects in them to the ground. Then send through the pigs to clean up all the fruit on the ground.

5.4.11 Methods of planting a landscape

A.k.a., Selecting a planting strategy, planting a restoration agriculture pasture, how to plant a landscape.

There are two primary planting strategies, one based on annual care and the other based on genetic selection:

1. **The plant and care strategy** - Plant a specific number of plants in specific locations and then care for their survival. This strategy is more optimized for an annual ecology. The general purpose here to plant and then to help the plants survive, when challenged, through extra inputs (e.g., compost tea, herbicides, fungicides, etc.).
2. **The genetic selection planting strategy (the observe and cull method)** - Plant way too many food-producing trees and shrubs in the early years. Remove the ones that don't bear at a young age. Continue to remove the ones that are susceptible to diseases and that are attacked by pests and continue to plant new seedlings and varieties year after year after year. Let the dynamics of population ecology kick in and let pest and disease populations stabilize. The cultivation wants the specific genetics that are pest- and disease-resistant and need very little care. This strategy produces a better perennial ecology. Plant more trees to start, and then cull 60-90% of the trees that aren't thriving. Forget about taking careful care of the plants. Practice strategic neglect (a.k.a., strategic total utter neglect) to see which genetics are best, then cull the rest.
3. **Succession method** - Plant species in a manner that follows the natural succession of plants in the area.

There are several ways to plant trees and other plants on a landscape:

1. In terms of locating:
    A. Placing - The location can be pre-planned and designed, and then the selected plants are planted in specified locations.
    B. Dispersing - The seeds can be scattered randomly and the plants will grow when they find the right growing conditions. This method creates patches of naturalized vegetation. This is also one method for selecting for better plant genetics; those genetics that don't thrive won't survive.
2. In terms of pre-growing:
    A. Direct seeding - placing or dispersing seeds into the ground soil.
    B. Transplanting - growing out the seeds in a pot and then transplanting them in soil.

Under the "plant and care" strategy mentioned earlier, it is relevant to note that when transplanting young trees (and other woody plants), there will be a much higher tree survival rate when the weeds are managed correctly. Weeds when unchecked and uncontrolled can take up moisture and nutrients from young trees, they can also produce compounds that inhibit the growth of the trees. Restorative farming uses symbiotic plants planted beneath the trees. Conventional farming uses herbicides that are compatible and listed for use with both the woody crop and the alley crop. If herbicides are not to be used, then light cultivation on either side of the tree row often works well. Additionally, organic mulches, when applied thick enough, can smother out weeds around newly planted trees as well as help to retain soil moisture. Such organic mulches often contain wood chips, bark, and sawdust (as coarse mediums). Straw and hay work as well, but not as well as wood cuttings. Note that straw and hay also tend to provide a habitat for bark-eating rodents, which is undesirable. Plastic mulches are sometimes used, but can increase the heat under the plastic and cause stress to the tree (in these cases, white plastic is often preferable to black). Geotextile and spun-polyethylene landscape fabric works as well. The textile and plastic products must be removed when their purpose is complete. It is relevant to note here that mulches represent quite an up-front investment in materials, labor, and cost. Rarely is mulch an option on larger plantings of several acres or more.

5.4.12 Methods of genetic selection

When initially starting a holistic cultivation system it is preferable to use seedlings (or seeded plants) and not grafted cultivars, because only the ones that thrive will survive (and, the others will be culled). Every seed is a genetically unique individual and the planter has no idea whether it will thrive or not under the local conditions. Grafted cultivars all have the same genetics. Individual seed genetics allows for the selection of those that rive and the culling of those that do not. Therein, buy in wholesale quantities and sell the rest to other farms or locations. Then, plant high density, close together (not 30 feet apart), then choose the ones that are performing well and cull the rest. Herein it is significant to note that soil tests will, essentially, always show deficiencies. However, there will still be plants that thrive under those conditions. Everywhere on planet earth there are plant communities that live healthy, vigorous, and vibrant lives and they show no deficiency symptoms in them. Yet, do a soil test anywhere, and everywhere it is done there are deficiencies. Everywhere on the earth there are plants that are site-adapted to grow there well. In this, humans can mirror and then improve upon an ecology. Identify a selection criteria for keeping, and if a plant doesn't meet the criteria then cull it. Plant seeds in nursery first, then when sprouted, plant them in an agroforestry row.

A common selection criteria may be:

1. Will grow very fast.
2. Will produce seeds within three to five years.
3. Will be pest free.
4. Will be disease free.

This produces perfectly site adapted plans with no major inputs:

1. No soil amendments.
2. No pest control.
3. No fertility control.
4. No disease control.

Repeat this selection, culling, and seeding process each year and over time the site will have a perfectly adapted perennial cultivation ecology. Once these site adapted plants are producing their own seed, then it may be useful to buy a grafted variety for its pollen. Every once in a while bring in variety.

5.4.13 Plant protection from livestock planning

There are circumstances where plants need to be protected from animals. For example, young trees need to be protected from foraging animals, which is often accomplished by means of fencing. In certain cases it may be necessary to have both electric and non-electric fencing stacked behind one another to sufficiently protect trees (and other plants) from grazing animals. Many livestock will damage young trees, or scratch or dig in the understory. There are breeds of livestock more and less compatible with a fully diverse herbaceous understory. A newly planted row of trees will need to be protected from animal foraging. Animals need to be stopped from reaching over the fence to forage young trees. Young trees need to be protected from foraging for 3-4 years. Note, however, that some trees (e.g., male mulberries) can be trimmed severely and the tops thrown to cattle, sheep, or goats to consume. Cutting male mulberries, for example, will not damage them like the female berry-producing plants, and will instead stimulate them to send up numerous shoots, which can be consumed by the livestock.

Animals can be rotated frequently to avoid hoof damage to tree roots. A portable two-strand polywire fence with a solar charger is all that is needed. For pigs, both strands are lowered to nose and ear height.

From the perspective of perennial grazing-adapted plants, the question is, how can livestock help the plants be healthier. Relatively short periods of occupation in a paddock so that are not grazing so long that not grazing the too short or re-grazing the plants as they are starting to grow necessarily. How long do plants need to regrow. This statistic is not fixed, and livestock should not be reintroduced until the plants have reached the right growing stage. This requires constant observation and monitoring. Develop a plan, then assume you are wrong, because the landscape can go off-tack with the plan and the plan will need to be adjusted. Coordinating a dynamic (constantly moving) biological system requires real-time adjustments.

5.5 Landscape modification using trees (agroforestry)

READ: *Agroforestry cultivation planning; woody-plant cultivation.*

Agroforestry implies integration of trees in a crop- and/or livestock-based cultivation [farming] system. Trees should match the soil type and microclimate and have multiple functions. Therein, agroforestry is farming that incorporates trees and/or woody plants in a regenerative manner. Agroforestry is the general process of re-wooding (adding woody species to) an environment successionally in order to change an annuals-based landscape to a perennial cropping system. Agroforestry is a set of food-forest intercropping cultivation techniques that combines agriculture, pastoral, and forestry techniques in one area. Note that trees and shrubs are considered part of the forestry system. These techniques are sometimes used to transition from an annual to a perennial cropping system. Agroforestry may also be considered transitional because it includes (or, commonly includes) annuals, and is not made-up completely of perennials. Agroforestry is used to describe a set of agricultural practices in which woody plants, especially trees, are integrated with annual crops and/or livestock on the same piece of cropland. The intentional inclusion of woody plants (Read: forestry) is to modify, to varying degrees, the local microclimate. Changes to the landscape often cause microclimate modifications, which can be intentional planned. In concern to restoration agriculture, agroforestry represents a transitional system that helps transform an annuals-based commercial operation to a more perennial (or, completely perennial) system. In other words, agroforestry may be used to bridge the gap between commercial annual and perennial cropping systems. Annual crops will always have a yearly or seasonal planting "cost", or at least require more energy and resources, more inputs, than a perennial polyculture. Annual agriculture is, in general, hostile to animals, by humanity, for their production, having to necessarily exclude and/or exterminate them to maintain the annual crop.

The first step in the agroforestry transition is the planting of trees, often in rows (curved or linear), and the alleys are used for growing annuals. Then, once the trees become established and are producing forage, the alleys are converted from annual crops to perennials (with a lot of grass, but also many other forage and perennial crop plants) and livestock are introduced. In a restoration agriculture system, as opposed to a pure agroforestry system, the landscape is "managed" by the grazing animals. In a restoration agriculture system, the animals do the mowing, the animals do the fertilization, and the animals do the pest control. A lot of the inputs that are required for regular agriculture are completed by the livestock or other natural processes. Soil on planet earth is created by perennial ecological system, so it is important to design an agriculture that is a perennial ecological agriculture, which is what restoration agriculture is all about. An within that context, some annual agriculture can still be done using alleycropping (an agroforestry technique). Agroforestry methods are relatively simple and universally applicable in nearly all regions of the world. It is relevant to note here that woody crops can take several years to become fully established and the tree-crop system must be designed and managed so that both the trees and the crops gets sufficient water and nutrition.

Woody plant selection includes the following functional considerations:

1. Microclimate modification.
2. Nitrogen fixation.
3. Food for livestock.
4. Harvestable products.
5. Functional biodiversity.
6. Conservation.
7. Aesthetics.
8. Woody plant must be adapted to the climate, site, and soil.
9. The establishment time of the plant.
10. Interaction with crops and/or other plants (e.g., shading, root habits, nitrogen fixation).
11. Pruning.

Woody plant selection and placement for light availability includes the following considerations:

1. Placement and distance from one another.
2. Row orientation (if planted in a row).

3. Alley width (if using alleycropping).
4. Leaf canopy characteristics - trees with different heights and different canopy structures will cast different amounts of shade and alter the microclimate in different ways.
5. Leaf phenology - when do the leaves leaf out (i.e., produce leaves) and when do the leaves drop?
6. Pruning considerations. Note: The edge of a row will likely cause the most cultivation maintenance, and what grows there needs to be carefully selected.
7. Protection considerations - protection from livestock, especially when young.

The designed orientation of rows and isles in a restorative cultivation system is contextually specific, but typically follows the following rules:

1. In a cool tempered climate, put the rows, alleys in a north-south orientation. That way the sun comes down and shines relative evenly on both sides of the tress (illuminated the alleys well). This orientation gives maximum sun to the alleys, be aude you are sun limited.
2. In a hot temperate or mideterranean climate, or a dry hit climate, it is typically best to have an east-west orientation, because the trees have a shaded side, and shade tolerant tolerant plants grow well there. This orientation gives some unique shed arrangements to protect some plants and animals from the hot sun.

It is also possible to mix orientations, but that may not be optimal. Go with what is ideal for the location giving what is being cultivated, and the movement of the sun throughout the year. It is relevant to note here that, a plant photosynethesis volumetric analysis can be done onto the 3D landscape to determine optimized photosynthetic volume of a given planting of plant species.

It is important to consider below ground competition for water and nutrients, and such considerations include, but are not limited to:

1. Alley width.
2. Root distribution.
3. Root pruning (e.g., tillage, subsoiling, etc.)

In agroforestry, trees (and their accompanying 3D plant layers) are commonly arranged in the following ways:

1. In rows (lines).
   A. Row on-contour layout.
   B. Row off-contour layout.
2. In grids (grid layouts generally ignore contours and hence, ignore the water and nutrient holding benefits that come with slowing and spreading water).
   A. Linear grids.
      1. Square - the distance from plant to plant and row to row is kept equal.
      2. Rectangular - the distance from row to row is less than the distance from plant to plant in any one row.
   B. In a triangular (diamond) shaped grids.
3. Dispersed randomly.

There are two basic types of agroforestry systems:

1. **Agro-silvi-cultural system** - a system that combines trees with crops.
2. **Silvo-pastural system** - a system that combines trees with livestock.
3. **Agro-silvo-pastoral** - a system that combines all three (trees, crops, and livestock).

Agroforestry practices/techniques include, but are not limited to (note: these practices can be combined, and their applications usually overlap):

1. **Natural visual barriers** - trees can act as natural visual barriers, giving people in specific locations more visual privacy (e.g., their homes and other private-type areas around the habitat).
2. **Water infiltration** - trees can facilitate the infiltration of water.
3. **Erosion reduction (erosion barriers)** - trees can reduce water and wind erosion. For example, trees placed along the side of a road/path to reduce water erosion on the path. Trees can be placed on slopes to hold soil together and reduce erosion on the slope.
4. **Windbreaks (natural wind barriers)** - row(s) of trees (or woody plant). These linear plantings of trees or shrubs are intended to mitigate the effects of the wind. Simply, Windbreaks are plantings of trees and shrubs designed to enhance crop production, protect livestock, people and structures, and benefit soil and water conservation. Windbreaks can be made of varying densities, allowing for more or less penetration. Additionally, windbreaks can be made of taller or shorter trees, involve a single or multiple rows. Windbreaks are often, though not always, made using evergreens or deciduous trees (or a combination). Evergreens are more impenetrable than deciduous trees. More widely spaced deciduous trees would be more suited for breaking up a driving wind and for scattering snow more widely. Windbreaks are often, though not always, linear in structure. Windbreaks interact primarily with wind patterns. Windbreaks can have the following benefits, including but not limited to:

A. Research suggests vegetable crop yield and quality can be increased through the effects of windbreaks (Baldwin, 1988, Agriculture, Ecosystems & Environment)
   1. They can help to prevent desiccation in field crops.
   2. They can prevent mechanical crop damage from wind-thrash and wind-throw. Here, they can also prevent the sand-blasting of delicate field crops (e.g., eggplants, melons, peppers, and squash).

B. They can help prevent wind-generated soil erosion (i.e., are a form of wind erosion control).

C. They can be used to protect buildings from wind-related damage and reduce winter heating costs.

D. They can create pleasant spots for human recreation.

E. They can be used to reduce wind-induced stress in livestock.

F. They can be used to block the line-of-site views, odors, and noise.

G. They can help to prevent chemical drift (as well as leaf and soil drift) in either direction, either from the site in question and from external sites (i.e., prevent chemical drift coming onto a site from outside). Trees planted as windbreaks for the reason of chemical drift are sometimes called sacrificial trees. Inexpensive, fast-growing, expendable trees like poplars good for this purpose.

H. They provide a wide diversity of habitats for numerous beneficial organisms from the obvious nesting sites for birds to the not-so-obvious alternative pollen sources and homes for native wild bees.

I. When planted along roadsides or driveways windbreaks can act as snow fences that reduce the need for snow plowing due to a reduction in snow drift accumulation (i.e., are a form of snow dispersal control). Multiple rows of trees can be used to catch snow in between them.

5. **Riparian buffers (a.k.a., perennial riparian buffers, riparian forest buffers; i.e., woody plants bordering a body of flow of water)** - Riparian buffers resemble windbreaks in that they are used to interact with an energy flow. Riparian buffers interact primarily with water patterns (not water streams, but overland water flow). Riparian buffers are often, though not always, linear in structure. These buffer zones act as mechanical filters and biological sponges. Buffer plants provide wildlife habitat and can attract pollinators. Runoff from the waterway or water body is filtered through the riparian buffer, which keeps nutrients and agricultural chemicals from washing into the water. Additionally, the perennial vegetation in a perennial buffer strip decreases velocity of water, increasing infiltration. Note that as the velocity of the overland water flow decreases, suspended particles often begin to settle out, the riparian buffer captures and accumulating soil. Perennial plants planted in riparian zones can tolerate being under water for weeks or months. With adequate water, nutrients and accumulating topsoil, riparian zones have the potential for higher yields than upland agricultural fields. An example riparian zone strategy may be to plant five or six rows of hazelnuts along the sides of a smaller stream.
   1. Note: Riparian zones are the area of land along the edges of bodies of water. In other words, a riparian zone or riparian area is the interface between land and a river or stream. The width of a riparian zone, immediately adjacent to any body of water, depends to a large extent on the size of the water body. Riparian areas are often flood zones.
   2. Riparian buffers have the following benefits, including but not limited to:
      i. They help protect water quality.
      ii. They reduce soil erosion.
      iii. They provide unique plant growing environments.
      iv. They provide habitat for aquatic and semi-aquatic organisms and other terrestrial wildlife.

6. **Alley-cropping (a.k.a., alleycropping, keyline alleycropping, silvoarrable; i.e., rows of woody plants separated by non-woody crops)** - the cultivation of food, forage or specialty crops between rows of woody plants (e.g., trees). In other words, it is the growing of a row of trees or shrubs (or both, and potentially other plants) in between annual or perennial crop fields. Annual crops can still be planted in the alley cropping system. Note here that the row of woody plants will create a windbreak and will add additional shade to the land. It is a larger version of intercropping (planting two or more crops in close proximity) or companion planting conducted over a longer time scale. The alley width should be at least the width of the widest cultivation/harvest machinery (if machines are beings used to harvest crops in the alleys). In the case of annuals planted in the alley, for the most efficient number of passes across a field, alley widths should be in multiples of two times the width of the equipment being used. The tractor travels up the field then back, up then back,

however many times it takes to reach a desired width. The trees that seem to do the best in alley-cropping systems are trees with taproots. Such trees do not have a shallow mat of roots to get compacted and damaged by equipment and they don't "steal" as much water and nutrients from the crop. Another technique to prevent nutrient theft is to drive a subsoiler along the row of trees every year from the very first summer after they are planted. This clips any young roots that attempt to go after the crop nutrients. Subsoilers can cut back roots extending into the pasture that would otherwise take nutrients away from alley crop. It keeps roots within the tree row and encourages them to dive deeper, instead of spread wider. If the tree is not subsoiled when young and is only subsoiled after the tree has grown large and the tree roots are much bigger, then the tree could suffer from all kinds of decay pathogens as well as it will not be as wind-fast (i.e., secure from wind). Root prune the alley cropped trees every year beginning in year one. If automated harvesting machines are to be used in an alleycropping system, then there must be sufficient space between woody plants for the machine to harvest nuts and/or fruits. Significant considerations for alleycropping systems include:

A. The shade density of the mature trees.
B. The number of trees planted per row.
C. The orientation of the trees. In a restoration agriculture system that has first installed a keyline water management system, the rows of trees would parallel the keyline. Instead of straight, rectilinear rows of trees, the trees would sweep along (or, near) contour; thus, revealing the natural shape of the landscape as it relates to water. Including, the location of shrubs and bushes
D. The potential benefits of alley cropping include, but are not limited to:
E. Improved microclimate conditions for crop growth.
F. Increased diversity of cultivation system.
G. Enhanced nutrient cycling and availability.
H. Improved soil quality and reduced erosion.
I. Increased functional biodiversity (e.g., improve pollination services, improve resistance to pests and diseases).
J. Watershed protection and an improved hydrologic functioning (through action of woody plant roots and a larger canopy).
K. Enhanced ecosystem services.

7. **Silvopasture (a.k.a., agro-silvo-pastoral; i.e., trees, woody forage plants, and livestock together)** - the intentional combination of trees, forage plants and livestock together as an integrated, intensively-managed system. In its most simple form, silvopasture is the planting of trees in a pasture. Trees reduce heat stress for livestock, increase their well-being, and provide fodder in times of scarcity. There are three general components to a silvopasture:
   A. Trees.
   B. Forage for the livestock.
   C. Livestock.

   Note here that allowing livestock to graze in the woods is not silvopasture and will likely result in inadequate nutrition for the animals and damage to forest regeneration. In general, these trees are cropping trees (i.e., harvest yielding trees, trees that produce crop) perennial woody cropping systems. Because of woody plants land becomes partially shaded by cropping trees. Trees produce food for people and foraging animals. Trees protect the slips from erosion. The general goal of a silvopasture is to have trees evenly spaced across a landscape. It is relevant to note here that when livestock crowd around one or just a few trees for extended periods of time the tree can suffer from overfertilization, the grass around the tree(s) will likely die, and root damage can occur. The ideal shade cast by the trees over the landscape is between 40-60% of the landscape being shaded. Moderate shading can reduce leaf temperature and transpiration, without reducing net photosynthesis in many plants (Diaz-Perez, HorScience, 2013). Livestock move through the pasture and always have sufficient shade. There is no need for the livestock to bunch up under one or a few trees when the shade is evenly spread. To turn a pre-existing forest into silvopasture requires clearing out the underbrush, removing undesirable and invasive species, opening up the canopy to let more light down, establishing shade-tolerant grasses, and grazing livestock. In silvopastures it is often best to plant deeply rooted trees. Trees with shallow roots can potentially suffer excessive root damage from animal trampling. Also, shallow roots can remove moisture from forage crops. It is relevant to note here that in most commercial silvopasture operations, livestock are the primary cash flow, and thus, high-quality forage production is the primary concern.
8. **Forest farming** - the intentional manipulation of the forest canopy and ground layer in order to improve the forest stand and to create ideal

conditions for an intensively grown, shade-tolerant crop. Note that forest farming is slightly different than forest gardening which is generally defined as the cultivation of a diverse, multi-layered system of useful woody plants are vertically integrated one on top of the other. Forest farming takes place in a closed-canopy, or nearly closed-canopy forest. Grasses and livestock forage require at least 40% light in order to thrive; however, typically forest farming takes place in forests with higher density and where the shade is more than 60%. Grasses, generally, do not thrive in this type of environment. Alternatively, other types of plants will thrive in a densely shaded environment, such as ginseng, goldenseal, gooseberries, currents, and fungi.

5.6 *Landscape modification using animals (animal agriculture)*

READ: Livestocked landscape cultivation planning.

The animal ecological sub-system must be planned.

5.6.1 Identify the animals

A.k.a., Animal selection planning.

Animals are matched to land type and stage of succession.

Identify and select the animals:

1. The animal species to include with the local biome, given the environmental conditions and succession of plants.
2. How many animals, and how many of each type, to include.
3. When to include them (e.g., when they have sufficient forage).

There are two important terms in rotational livestock grazing:

1. **Stocking rate** is the overall number of animals on the farm.
2. **Stocking density** is the number of animals in a specific paddock at a specific period of time.

Stocking rates (animal density) - identifying how many animals should optimally be on the pasture. The stocking rate is significant in concern to overgrazing in two ways:

1. Overstocking a pasture with one type of livestock, and not rotating them to new pasture, will lead to overgrazing. Overstocking can degrade pastures by removing more living plant matter than can regenerate before the next round of grazing.
2. Understocking a pasture can also lead to overgrazing. When few animals eat only their preferred forage and leave less palatable forage as well as noxious weed , as the season progresses the undesirable forage goes uneaten and slowly grows stronger and more woody, and sets seeds. This eventually produces a pasture full plants undesirable to the animals. By allowing the animals to eat only their preferred forage and not removing the unpalatable plants, only a few animals can destroy a previously abundant pasture. Understocking can degrade pastures when not followed up by finish mowing or grazing with other animals in order to prevent undesirable plants from proliferating and setting seed.
3. Set-stocking (continuous grazing, extensive grazing) is leaving livestock in the pasture for the whole year.

When the forage quality is high it will support more animals. More animals provide more fertilizer, in the form of manure and urine, to the plants. However, too many animals clustered around one or a few trees for too long can damage the tree and landscape.

The common sources of overgrazing include:

1. Overstocking a pasture - too many animals.
2. Understocking a pasture - too few animals.
3. Not rotating animals - the animals are never rotated to new paddocks/pastures.
4. Placement of water, shade, and supplemental food - placement of a water, shade, or food source in a field may cause the animals to graze close to the source, thus causing overgrazing in that area.

Overgraze of animals causes of land degradation and desertification. Degradation of land from overgrazing is used by proponents of animal confinement operations as a propaganda tool to eliminate the small graze or rancher as competition in the food markets.

5.6.2 Identify animal succession

Identify which animals should be placed on the land first, and the succession of animals (i.e., their introduction) over time.

5.6.3 Identify the functions of the livestock

There are several key functions that livestock can perform on a landscape, these include:

1. Site preparation.
2. Tillage.
3. Mowing and grazing.
4. Insect control.
5. Weeding.

6. Picking up harvest drops.
7. Fertilization (with manure).

5.6.4 Identify how many paddocks

For all methods but continuous grazing, a whole pasture is subdivided in paddocks. A good start may be to sub-divide the 1 pasture into 14-15 paddocks. Then, for example, in a mob-stocked, intensive grazing system with cattle, the cattle would only be in each paddock for 1-2 days. Thus, giving 1-3 weeks of rest per paddock.

5.6.5 Identify the animals movements (animal rotation planning)

Identify the daily or cyclical movement of the animals through the pasture or paddocks. The observing intersystem team cultivation member ("farmer") should observe and apply a set of grazing rules dependent upon the observation. A good general grazing rule is: by the time the last livestock species vacates a paddock, there should be no odd patches of ungrazed plants. Pastures recover more evenly and require less finish mowing when they are evenly grazed. In general, the ideal movement of livestock is to have them eat all of their possible first bites, or all of the plants that are intended to be eaten, and then move them to the next paddock.

5.6.6 Animal paddock movement

Movement considerations for animals ought to account for plants and changes in plants over season and year:

1. Changes in the [plant] systems during a single season.
2. Changes in the [plant] systems through the years.

There are many different ways of rotating multiple species of animal [in a leader-follower procedure] around a set of paddocks. In other words, there are many different arranges of leader-follower system.

5.6.7 Simplified example of landscape modification using animals

A simple example may be a to start with cattle. Cattle are the first because they are the pickiest (i.e., fussiest) grazers. Sheep and goats can follow behind grazing on the remaining lush forage, but most importantly cleaning up the re-sprouts and will also eat less desirable and more woody plants, even plants that are toxic to cattle (e.g., larkspur and leafy spurge, are readily consumed by sheep). Pigs can follow behind everyone grazing the “second bites” that the others ignored. When early "fall" fruit drops, hogs are the perfect way for a farmer to take the normally unharvestable wild fruit and nut crops. Also, cattle, sheep, goats and hogs all love to eat the leaves of various woody plants.

A more complete example of a rotational leader-follower grazing system:

1. **Start with cattle.**
   Cattle are grazers, and prefer longer grass; they will tend to not eat grasses too low to the ground if possible. Intentionally plant feed species for cattle foraging. Grass is the top feed species for grass. Grass comes relatively early on in the process of natural plant succession. Also, cattle are almost the fussiest grazers desiring the highest quality forage. Cattle graze by taking a bit from the top of the most nutritious pasture according to their needs. They will then move on to the next first bit, and so on until all of their preferred pasture has been bitten. They will then move back over the pasture and take the next bite down the stem, moving into less and less nutritious forage. In the simplest leader-follower example, young cows (calves) are moved into a paddock first; they have the highest nutrient demand of any cow life stage and will take the best of the best pasture bites. Once the young have grazed their first bit for the whole pasture, and before they begin the second bite stage, they are then moved on to the next pasture where they can continue to graze the most vital and nutritious feed. Lactating cows are then moved into the pasture that the calves have now vacated. This system allows for optimal weight gain in the calves and will not reduce milk production in the lactating cows. The system can be refined even further. The calves can be grazed first, and the cows can be divided into two classes based on their production. The heaviest milk producers can be moved into the pasture behind the calves, then the lighter producers behind the heavy producers. Dry cows can follow behind. This grazing system matches pasture growth. On a pasture, first bites are the smallest portion of available feed. This matches with the smaller size and high nutrient needs. Older cows require more bulk and dry matter in their diet, which matches what is available after the leaders move through. Simply put, one or more waves of cattle have grazed through a paddock first, with the calves eating the tips of the most nutritious plants, the best cows taking the second bites, lower-producing cows taking the thirds, and dry cows the fourths.
2. **Hogs (pigs) follow the cattle.**
   Pigs eat almost anything (not brush or thorny plants), and with their snouts will turn over the soil in search of roots and grubs. They also have the helpful habit of eating the roots of invasive species, which eliminates the need for herbicides. Intentionally plant feed species for hog foraging.

Once the cattle have moved through the system, then the pigs are moved in. Pigs are a broadly omnivorous animal. and use hogs with nose rings to prevent rooting up the pasture. Naturally, when pigs are turned loose in a forest, they will root up the ground and destroy forest seedlings. When left to themselves, they graze green forage, but they prefer to root through the ground to graze plant roots, grubs, and worms. In season, they eat dropped fruits and nuts. Hogs are used for pest control when they graze through the cultivation system to harvest the pest infected "June drop", and after harvest, when they eat the pest riddled fruit that pickers toss on the ground. Pigs will also sometimes eat snakes, rodents, and ground nesting birds. Pigs often disturb the ground more than other animals and this soil disturbing behavior can be used just prior to planting grain/ grass seed crops for when the cattle return. Pigs should not be allowed to diminish forage health by rooting it all up. In order to do this, nose rings are recommended. One nose ring across the columella (the fleshy part between the nostrils). And another into the tip of the snout. The procedure is painful when performed (like when a human gets a piercing), but the pigs stop complaining after the procedure is complete and it causes no long term damage to the animal. Note however, when the pigs try to root in the ground the ring will cause discomfort, thus teaching them to graze for food more than rooting. Some breeds of pig learn more quickly than others. Insertion is best done immediately after weaning or as soon as feeder pigs are received on the farm.

A. With a "pigs following cattle" system a rule of thumb would be to have no more than two mature pigs per adult cow. Fewer than two pigs per cow works just fine. With too many pigs they'll not have enough leftover forage to thrive, they will get hungry and begin to break through electric fences. Pigs are incredibly intelligent animals and once they learn that it only takes one zap to run through an electric fence, they will do exactly that if they are not getting enough to eat in their paddock.
B. Different breed of pigs root to differing degrees; some pigs root more (or less) than others. Some breeds of pig do almost no rooting.
C. Plant small grain or preferred crop for when the cows come back on rotation.

3. **Turkeys (and other fowl) follow the pigs.**
Intentionally plant feed species for fowl foraging. Once the cattle have grazed off their first two bites, and after the pigs have cleaned up behind the cattle, turkeys are an excellent choice to follow. Turkeys will nibble grass and forbs and there will be some left for them, but they prefer to eat big seeds and insects. Turkeys will eat the insects attracted to the dung left behind by the larger grazers as well as any seeds that may have passed through the gut of the animals that went before. They will scratch around in the grazed and trampled debris in search of beetles, caterpillars, worms and large seeds. Many pasture "weeds" that don't provide the best forage for cattle and pigs have large seeds. These large seeds will be eaten by the turkeys and ground into manure in the bird's gizzard. Turkeys (and all fowl) are also a great way to introduce mineral amendments to the pasture in a low-cost manner over a period of time. To have a high-yielding pasture, whatever minerals are low can be placed in a mineral feeding box and dragged from paddock to paddock with the turkeys.

A. Coarser-grit minerals are often times less expensive than the finer particle sizes of minerals simply because less milling time went into their production.
B. As the turkeys graze the pasture they are ingesting the spectrum of minerals available in that pasture. They will be internally deficient in whatever minerals are deficient in the pasture soil. All fowl instinctively will pick at the grit that supplies them with the missing ingredients that they need. The grit gets ground to a fine powder in their gizzard, it gets acted upon by the bird's digestive acids and enzymes, and what isn't used by the organism itself gets defecated onto the very pasture that needs that very mineral. Turkeys, especially the more intelligent, heritage breeds, are quite low maintenance and only one flock need be raised all during the summer grazing season.
C. The turkeys really aren't that much of an impact on the pasture itself, and so the green growth begins to rebound.
D. A good rule of thumb is approximately two turkeys per hog is an adequate number.

4. **Sheep can follow the fowl.**
Sheep are also grazers, but they prefer shorter grass, and tend to clip the grass low to the ground. Sheep, like goats, are especially good for eating more coarse vegetation than cattle and thrive. Sheep are the finish mower of animal polycultures. Intentionally plant species for sheep (as well as use sheep to clear out weeds).

A. With little else to eat the sheep happily graze on these broadleaf plants. Over time these weeds will become less and less prevalent in the pasture thereby providing weed control as a side benefit of the grazing system.

B. Generally a pasture has the same number of sheep as there are cattle.

5. **Goats can follow the fowl.**

They are without a doubt the animal that is able to produce high-quality meat and dairy products on the coarsest, most degraded forage. There are loud breeds of goats and there quiet breeds of goats. Archaeologists, anthropologists and historians have discovered evidence over and over again that goats are the last several phase before total desertification. Over time, as pastures degrade, fewer and fewer cattle can be maintained on the pasture and sheep and goats are then kept. If pasture quality is not maintained and the forage is overgrazed or incorrectly grazed, cattle and hogs give way to sheep and goats which give way to a desert. (Restoration Agriculture, 82)

A. Goats will jump fences, easily.

6. **Chickens can follow the sheep/goats.**

Following the sheep come fowl. Chickens scratch apart manure piles in search of grubs and maggots. This behavior not only spreads fertilizer on the fields, but also contributes to the desiccation and death of parasites, as well as providing a natural control of insect pests such as flies, ticks and fleas. In nature, chickens eat insects, worms, and some grain. As the chickens move through the pasture following the sheep, they scratch up any remaining manure from the "leaders" ahead of them searching for insects and seeds. If no supplemental feed is provided then fewer chickens can be supported. Wherever fowl mobiles are placed there will be a lot of high nitrogen manure deposited. It is good to part these mobiles in different locations on the paddocks through time to really spread out the manure. Intentionally plant species for chickens. Obviously the fowl will put manure throughout the rest of the paddock too, but with an open bottom mobile, a lot of manure will be deposited under the mobile.

A. Chickens come in three general types:
   1. Egg layers.
   2. Meat birds.
   3. A combination of the two.

7. **Geese can follow the sheep/goats.**

Intentionally plant species for geese. Geese have a special role in managing the understory of a food forest. To my knowledge they are the only species of livestock which eat only grasses and clovers, while leaving other crops alone. In the wild, geese are migratory birds. The eating habits of geese are similar to sheep. Geese graze on broad-leaved plants, insects, fruit and nuts, and are good for following turkeys. Fencing that is set up for pigs and turkeys will also contain geese without any adjustment.

A. Characteristics about ducks and geese:
   1. Ducks and geese need a pond.
   2. Ducks and geese are best not kept with chickens. This is mostly for cleanliness reasons, unless there is sufficient land and water space.

6 Plant cultivation specifics

A.k.a., Vegetation cultivation specifics, plant farming specifics, vegetation farming specifics, plant agriculture specifics.

Plant cultivation is the act of caring for, raising, harvesting, using, and composting plants.

The cultivation of plants includes the following human support functions (plant utility):

1. For animal nutrition (food, spices, feedstock).
2. For animal medicine.
3. For other plants.
4. For human aesthetics.
5. For other material resources (timber, fiber, fuel, etc.).
6. For research purposes.
7. For decomposition and chemical cycling.

Some essential phases needed for successful cultivation of the plants includes:

1. Medium and/or field selection: As per requirement of the plants (and farmer), the field and/or medium should be selected. In the case of soil, the selected area should be fertile soil, sufficient water, and light for the specific plant.
2. Plant selection, preparation, and initialization: As per the climactic bio-region and disease presence, the cultivated plant species and genetics should be selected. Plant propagules can be directly sown/grown or indirectly through nursery preparation. Different plant species and different planting methods will determine the distance between plant to plant and the angles between plants.
3. Coordination of the plant cultivation system includes:
    1. Weeding: Weeds should be removed from the field. This practice should be done in before and after the cultivation of the Plants.
    2. Watering: is necessary in some amount for plant life. A suitable amount of water should be provided and the plants should be protected from water stress as well as water logging.
    3. Fertilizing: Each nutrients that may be micro and/or macro nutrients playing a key role in plant life so, as per need of the plants these should be supplied.
    4. Diseases preventing: In different stage of a plant's life various diseases may appear and should be controlled by suitable measures. Suitable measure may include the culling of the plant in restorative agriculture or the using of a chemical in agro-chemical agriculture. In the latter case, the plants may need to be continually protected from biotic and abiotic factors.
    5. Harvesting: After complete maturation of the plants, they may be harvested (or grazed, even before complete maturation).
    6. Storage: Harvested plant parts should be stored in a manner that protect against microbial infection, fungal infection, viral infection, etc.
    7. Composting: A location and process needs to determined for the composting of plants and other organic matter.

6.1 Plant life overview

Plants perform both photosynthesis and respiration. During photosynthesis they absorb carbon dioxide, bind the carbon with water to form glucose, and release the oxygen. During respiration they absorb oxygen and release carbon dioxide. Most plants release 2 to 5 times more oxygen during photosynthesis than they use during respiration. When attempting to improve plant productivity farmers manipulate the plants environment to increase this ratio sometimes aiming as high as 40 times more oxygen produced than consumed.

The photosynthesis equation:

1. Plants use light for energy.
2. Plants take water and CO2 and combine them into sugar and oxygen.
3. Nutrients are not in the photosynthesis equation.

The nutrient component:

- Nutrients are the calories that support exercise. Exercise is the light. Nutrients balance the plant with its environment.

There are three primary types of plants as categorized by their lifespan that may be present in a plant cultivation system:

1. **Perennials** - return every year (keep living), and grow for many growing seasons. Perennials need to be planted once. Perennials are mostly ever growing.
2. **Annuals** - die at the end of a year. Annuals need to be planted annually.
3. **Bi-annuals (biannuals)** - are plants that normally live for two years before dying. However, like self-seeding annuals, biennials are also known for dropping seeds, which bloom two seasons later. If yearly bi-annual flowering is desired then it is often optimal to planting them two years in a row; that

way the two crops will alternate blooming.

For all known plants, each year, a percentage of collected solar energy is used to build its body. In the case of annual plants, the plant needs to build its entire body structure every year. This is not true with perennial plants. The plants keep their body structure from the previous year and add to it in every subsequent season, thus expanding (relatively) their surface area exposed to the sun and atmosphere. This confers a three-dimensional advantage not accessible to annual plants. Some perennial plants can live a relatively long time, and continue to produce food for other animals year after year with no human intervention.

6.1.1 Plant life cycle

The phases of plant life growth and death include:

1. Seed.
2. Germination.
3. Seedling/sprout.
4. Vegetative.
5. Pre-flowering.
6. Flowering and fertilization.
7. Fruiting and seeding.
8. Death.

6.2 Plants and soil

In nature, plants primarily grow in soil. Different plant genetics thrive in different compositions of soils. Soil is created from physical, chemical, and biological elements:

1. Physical factors
   A. Soil composition
      1. Sand, silt, clay, also contains, water, and air (gasses).
      2. Solids, liquids (in solution), gases
      3. Size of solids
      4. Sand is often largest (2mm to. 05)
      5. Silt (. 05 -. 002)
      6. Clay is .002 and less.
2. Biological factors
   A. Macro fauna - invertebrates, earthworms, ants, beetles, termites, etc.
   B. Mesofauna - bodies of 02—2mm.
   C. Microfauna - protozoas, bacteria, fungus.
   D. Other microorganisms.
3. Chemical factors
   A. Elements:
      1. Nitrogen, phosphorus, potassium, calcium, magnesium, sulfur.
      2. Magnesium, mangenese, chloride, nickel, selenium, boron, zinc, iron, molybdinum, etc.
   B. Processes:
      1. Potential hydrogen (pH) scale 1-7-14 (acid to alkaline, base).
         i. Nutrients are most available from 6-9pH. Depends on soil, location, and what plants prefer. Nutrient lockout occurs when the pH gets to acid or base.
      2. Capacity of exchange of cations (CTC).
      3. Leaching.

6.2.1 Making soil

There are two ways of making and regenerating soil:

1. Using natural **ecological processes on the landscape**, referred to as holistic pasture cultivation (a.k.e., restoration agriculture, holistic agriculture, etc.). Allowing animals and plants to live their normal lives across a care-taken landscape.
   A. **Plant body composting:** Plant composting is a natural process of decomposing plant materials, such as leaves, stems, and other organic matter, into nutrient-rich compost. This decomposition is facilitated by microorganisms, including bacteria and fungi, breaking down the plant material into humus, a valuable soil conditioner.
      1. **Composting using micro-organisms** (i.e., using bacteria and fungi) produces "humus" soil.
      2. **Composting using worms** (a.k.a., vermiculture) produces a vermicompost. Worms are toothless animals that will eat the substrate they live within. Worms need some type of grit in their bedding that they can swallow and use in their gizzard to grind food.
   B. **Animal body composting:** Animal composting is a natural process of decomposing animal materials into nutrient-rich compost. This decomposition is facilitated by microorganisms, including bacteria and fungi, breaking down the plant material into humus, a valuable soil conditioner.
   C. **Animal excretion:** Animal excretory producta ("waste") can be directly deposited on the ground to create soil, or it can be added to specific composting systems.
2. Making a bio-amendement to compost in the form of **a human-made bio-chemical solution** applied as an amendment to a landscape area to produce better soil conditions (e.g., terra-preta).

6.2.1.1 Amending/making soil better with terra-preta

A.k.a., Bio-char, biochar, black soil, black earth, compost tea, bio-amendment to compost, etc.

Terra-preta (black soil) is a compost mix with live useful bacteria that is added to soil/dirt to produce better plant sustaining conditions. Terra-preta (black soil) is made in the following way:

1. Get ingredients: charcoal, cassava, (yuca, yucca, tapioca), and water. Cut cassava tuber in 4-10 cm slices.
2. Create fermented cassava water by placing the tapioca in water and letting it sit and ferment for 7 days (up to 3 months).
    A. Add foliage organic material from plants (as much as desired, and before or after fermentation).
    B. Add manure organic material from animals (as much as desired, and before or after fermentation).
    C. Add rock dust mineral material from rocks (as much as desired, and before or after fermentation).
3. After 7 days, mix the cassava compost tea water with charcoal.
4. Mixed the solution/slurry around, and then
5. Spread the solution on a landscape by mixing the solution into the local earth.

Soil is composted of minerals, organic decomposing materials, worms, insects, fungi, bacteria, and other elements, all of which are essential for healthy soil. This bio-diverse ecology ought to be protected from extreme heat and solar radiation. Just like soil can be turned bare by water and wind, it can also be literally be cooked by the sun. The harm is that soil temperature directly affects the biology within the soil, and consequently, plant growth. When soil reaches 21c (70F) degrees, water evaporates and carbon oxidizes. Once soil reaches 60c (140F) degrees all moisture is gone and the beneficial bacteria and microorganisms are dead. Here, the reverse of photosynthesis occurs. Instead of plants actively drawing down carbon and releasing oxygen, carbon is mixing with oxygen and releasing into the atmosphere. Dry, bare soil also heats up faster and to temperatures higher than ambient air temperature, which accelerates evaporation.

6.3 *Plant cultivation locations*

There are several locations that plants are cultivated in the habitat service system; there are the following locatable mediums:

1. **Soil cultivation:**
    A. In earth soil (including at surface, below, and raised).
    B. Potting (using pots, containers from the small to the large).
2. **Soil-less cultivation:**
    A. Aquatic natural (e.g., natural ponds).
    B. Aquatic-liquid controlled (e.g., hydroponics, also a potting type-of cultivation).
    C. Atmospheric-moisture controlled (e.g., aeroponic, also a potting type-of cultivation).

Plants grow all over the planet in different climates and upon different landscapes, wherein locations can be classified according to:

1. **Landscape (objects):**
    A. Top-soil type.
    B. Underground soil layering.
    C. Water table.
2. **Soil (objects):**
    A. Presence.
    B. Makeup ("quality").
3. **Climate (dynamics):**
    A. Atmospheric humidities over a year.
    B. Rainfall and rainfalls over a year.
    C. Temperatures over a year.
    D. Seasonality over a year.
4. **Local ecology (dynamics):**
    A. Interrelationship of animals, plants, and landscape over continuous time.
    B. Local, regional, and global ecological service availabilities.
    C. Local, regional, and global ecological service health ("quality").

6.3.1 Allopathy

Allelopathy is a characteristic of plant organisms, who produces biochemicals that influence the growth, survival, development, and reproduction of other organisms, particularly, plants in nearby soil. These biochemicals are known as allelochemicals and may either have [intentionally] beneficial or detrimental effects on target organisms in the environment. Plants can directly kill other plants through biochemicals released from their roots, plants can also take away nutrients from other plants through this biochemical process.

6.4 *Plant cultivation tracking*

Plant cultivation resource analysis factors include, but may not be limited to:

1. Location coordinates with centimeter GPS location accuracy.
2. Plant classification and identity (some standardized ID that relates to a specific plant species).
3. Approximate age/growth stage.
4. Last known size.
5. Previous treatment history.
6. Previous production history.
7. Plant health status.
8. Plant size status.

9. Plant life-phase status.

6.5 Plant propagation methods

A.k.a., Vegetative propagation, human spreading of plants, multiplying of plants.

Plant propagation is the process of creating new plants by reproducing them from existing ones. It involves various methods to multiply plants, allowing gardeners, horticulturists, and farmers to propagate plants with desirable traits, reproduce rare species, and expand plant populations. Plants can be propagated (spread) via the following methods:

1. **Seeds (seeding):** Propagation via seeds involves collecting, sowing, and germinating seeds obtained from the parent plant. Seeds are reproductive structures produced by flowering plants and contain the genetic information necessary for the growth of new plants. This method is versatile and applicable to a wide range of plants, offering genetic diversity (i.e., diversity of life). It is used for annuals, biennials, and some perennials.
2. **Cutting propagation:** Cutting propagation involves taking a piece (cutting) of a healthy plant (stem, leaf, or root) and encouraging it to develop into a new plant. The cutting is placed in a growing medium where it roots and develops into a new individual. Types of cuttings include:
   A. **Stem cuttings:** Taken from the stem of a plant.
   B. **Leaf cuttings:** Involves a single leaf or a portion of a leaf.
   C. **Root cuttings:** Sections of roots that produce new shoots.
   D. **Leaf-bud cuttings:** Includes a leaf and a small portion of the stem with a bud.
3. **Division:** Division involves separating a mature plant into several sections, each having roots, shoots, and leaves, to create new plants. This method is common for perennials like hostas, ornamental grasses, and irises.
4. **Layering:** Layering encourages roots to develop on a stem while still attached to the parent plant. Once roots form, the stem section can be separated and grown as an independent plant. Methods of layering include:
   A. **Simple layering:** Burying a section of a stem while it's still attached to the parent plant.
   B. **Tip layering:** Bending the tip of a stem into the soil and allowing it to root.
   C. **Air layering (Marcotting):** Encouraging root formation on a stem without burying it in the soil. Instead, a section of the stem is wounded, wrapped with a rooting medium (e.g., soil), and enclosed in a moist environment until roots form. Once the roots have formed and are sufficiently long, the stem is cut off below the roots and placed in the soil.
5. **Grafting and budding:** Grafting involves joining two plant parts (a scion and a rootstock) to create a new plant with desired characteristics. Budding is a type of grafting where a single bud from one plant is inserted into the bark of another plant to grow.

6.6 Plant cultivation methods

A.k.a., Plant cultivation techniques.

Plants can be cultivated by several different primary methods.

6.6.1 Ecological cultivation of plants

A wide variety of plants can be cultivated for both humans and livestock animals using a variety of techniques that apply ecological principles to a landscape. This method refers to cultivation on the soil of a landscape These sets of techniques are often given the following common names:

1. Restorative agriculture.
2. Permaculture.
3. Agroforestry.
4. Nursery.
5. Etc.

6.6.2 Plant nursery from seedling to youngling

A.k.a., From seedling to treeling cultivation, from seedling to crop instantiation.

A future pasture plant starter area for larger plants provides to function cultivating (growing) seedings to treelings. An area inside the dwelling sector has been designated for this function. This section of dwelling area landscape doubles as a functional section for the . So basically what we can do in this section is we can initialize the growing of trees and other plants. Because seeding is preferred over cutting for the pasture. This location is a place for planting seeds and having them grow into trees, and then, we uproot them and replant them in the pasture. We then fill in the hold with fertile soil and reseed. The area around the plants is covered by wood chips to prevent the growing of weeds. The herbicide used here is a vinegar solution. The wood chips on the ground help to create a good environment for the growing of these plants. The seeds are planted in the sector and grown a bit, then transplanted into the pasture, and protected for as long as appropriate from grazing animals.

NOTE: *The nursery method is not necessary the opposite of the STUN method of restorative cultivation that relies on throwing seeds, seeing* *what thrives, and killing/cutting-back the rest. It is similarly possible to plant several treeling-type plants, see which thrives and cull the excess.*

6.6.3 Controlled environmental agriculture

Here, the environmental dynamics of the cultivation system are highly controlled by the cultivator, using specialized technical systems, including:

NOTE: *These controlled system can consume large amounts of electricity, for illumination and water movement.*

6.6.3.1 Monocropping agriculture

Plant monocopped agriculture takes a large area of land and cultivates one, possibly more, species of annuals on that land.

6.6.3.2 Aquaponics (a.k.a., water agriculture, acquaculture)

Aquaponics is the practice of fish farming combined with the cultivation of plants in water without soil.

6.6.3.3 Hydroponics (a.k.a., water cultivation of plants)

Hydroponics is the practice of growing plants in specialized, enclosed, water-based systems. Hydroponic systems can take on the form of localized vertical farms. The new systems are designed to produce a sanitary crop, grown without pesticides in hygienic buildings monitored by computers, so there is little risk of contamination from pathogens.

Although the nutritional profile of hydroponic produce continues to improve, no one yet knows what kind of long-term health impact fruits and vegetables grown without soil will have. It is relevant to note here that no matter how many nutrients indoor farmers put into the water, it is extremely challenging, if not impossible for indoor farms to match the taste and nutritional value, or provide the environmental advantages, that come from the marriage of sun, a healthy soil and soil microbiome, and plant biology, found on well-run holistic farms. Trying to enhance water with nutrients to mimic what soil does is virtually impossible, in part, because it is not yet known how the soil microbiome works.

6.6.3.4 Potted soil cultivation of plants

Plant pot material composition types:

1. Cloth-type fabric pots
2. Ceramic and clay pots
3. Concrete vessel pots
4. Plastic pots
5. Etc.

Some of these types of pots have a much higher replacement rate than others. For example, cloth-type pots often need to be replaced in a cycle based upon a set number of weeks or months (due to buildup of organic and inorganic materials and the deterioration of the fabric).

Some pots can have secondary functions, such as:

1. Air pruning pots - root bounding occurs when the roots of a plant contact the side of a solid container where they have nowhere else to go to find air. The roots then begin to circle around the side of the pot. One solution for root bounding is transplanting the plant in a larger planter (i.e., pot). Some plants, trees in particular, can become so root bound that they essentially "strangle" themselves. When the roots hit the side of an air pruning container, the roots air prune themselves, and begin to branch their root system throughout the container. The aerated area around the outside of the plant is an environmental stimuli to which the plant responds to by branching its root system.
   A. Low density air pruning: cloth, fabric, and geo-textile pots.
   B. High density air pruning: multi-hole mesh pots.
   C. Self-watering (sub-irrigation) pots.

   NOTE: *Depending upon the plant type, usage requirements, and desired growing environment, some plants are better pot bound.*

The common growing mediums for pots are:

1. Soil - soil mixed well with 30% perlite to help with drainage and allow more air/oxygen to come into contact with the roots. Without perlite or another coarse medium, water input from the top may not drain to the bottom root, and the dense packed soil may choke off the roots.
2. Compost additive.
3. Manure additive.
4. Coconut coir chips - more renewable. Comes from the husk of coconuts. Drains well.
5. Peat moss - less renewable. Comes from peat bogs, which are not highly renewable. Peat has a cation exchange capacity - it has the ability to absorb nutrients and hold them away from the plants roots as the medium dries out, then when the peat is rehydrated (i.e., watered), the nutrients are released.
6. Water (aerated).
7. Air (humid).

6.6.3.5 Method to grow big healthy plants under controlled conditions on the landscape

The following is an optimized method for the cultivation of plants under controlled conditions in order to optimize their size, health, genetic expression, and nutrition- or other-use value for humans:

1. Get seeds:
   A. Get the right genetics.
   B. Get normal and/or feminized seeds.
   C. Do not use autoflower seeds as they will produce a lower yield, because they can flower automatically and the grower will have less control.
   D. Do not use clones because as clones grow they will shoot off only 1 node every 90 degrees. If you use seeds, it puts off bi-symmetrical nodes (two nodes, each 180degress opposite one another).
2. Do not stress plants out while they are babies.
3. Do not let plant get too root bound in the pot. Also, do not move plants without sufficient roots.
4. Six foot diameter pot in the ground with mesh wire in ground to protect the plant from underground predators. Line the mesh with plastic so there is no leaching from other water sources.
5. Use a bubble irrigation drip. Overhead sprinkler often lead to a lot of water evaporation prior to reaching the soil.
6. Reuse soil year after year and monitor for buildup of nutrients.
7. Use seasonal cover crop.
8. Spread out leaves so there is more surface area exposed to the sun. The plant will grow bigger because of this. A cage around the plant can be used to pull the branches apart. Tying them around the cage. This pulls the plant wider. Generally you don't want to pull them down if they are outside, because you have space, so instead, you pull them up slightly by tying them to an surrounding cage at a slightly higher elevation than the branch itself.
9. Filter city water to remove chlorine, chloramine, etc. inline with the water hose.
10. Prune only as needed. Especially leaves at the bottom that won't get any more or much sun.
11. Pre-planting techniques (i.e.,techniques before planting the plant in the ground):
    A. Cut off the two bottom branches (generally the very bottom are just leaves) when there are 12 node branches total (generally, about 4 inches tall).
    B. Top the plant at the same time you plant the plant in the ground. This early stage topping is sometimes called "pinching".
12. Stretching techniques (a.ka., tying) to stretch the plant during growth:
    A. Start by tying outward and upward in a cage. Keep moving outward and upward. In this method, once the plant is outside of the cage, tie them down toward the soil while pulling them out.
    B. Start by tying outward and downward into the soil. Keep moving outward and downward.
    C. Some genetics are harder to tie down because the branches are not as flexible and will snap.
13. Mesh/screen supporting technique (a.k.a., scrogging):
    A. When the plants get really big, use a screen placed horizontal to pull and separate out the leaves.
14. Cutting techniques:
    A. Pinch off growths that are not useful.
    B. Cut the emergent top(s) off the plant.
15. Nutrition and medium:
    A. Soil mix - Mix it all together in a wheelbarrow. Re-use the soil. There is no need to dispose of the soil, simply re-use it.
       1. A good example of a quality soil mix is:
          i. Roots Organic 7-0-7 with black gold - half a bag of each.
          ii. Ancient forest - half a bag.
          iii. Ocean forest - half a bag.
          iv. Alaskan humus - whole bag, because it is a small bag.
          v. Hydroponics clay balls (clay pebbles) - these gather the nutrients and that would otherwise be lost downward and slowly release then. They also provide aeration. 10-15% of whole mix is made up of the clay balls.
    B. Make compost tea and feed it to the soil and roots of the plant on some set feeding cycle. Be careful using compost tea if it is very hot with nitrogen as it could turn the bottom branches yellow. The compost tea may contain any combination of the following:
       1. Worm casting.
       2. Wood compost.
       3. Carbohydrates (succanote crystals, molasses, etc.).
       4. Boogie base (or supersoil recipe).
       5. Wood chip compost.
       6. Biochar.
       7. Insect frass (black soldier fly insect frass, enetrofly, comes from canada).
       8. Minerals.
       9. Fungal spores.
       10. Additional feeds:
           i. Crab mill.
           ii. Kelp mill.
           iii. Feather mill.
           iv. Glacier rock.
           v. Oyster shell.

vi. Neem seed (on top, and double the amount of neem compared to 1-5).
vii. Biochar - char that adds carbon to the soil. It is important to "activate" it before adding it to the soil otherwise it will bind nutrients.

16. Nutrient foliar spray (foliar feeding):
    A. Spray compost tea on plant.
    B. Spray protein solution on the plant.
    C. Then spray run water for 15 minutes to disperse sprays.
17. Have the plant search for water, so the roots spread out more.
18. Kill bugs (note: if using the STUN technique and a plant is overwhelmed with bugs, then the plant will be killed. If not using the STUN technique, then kill the bugs and save the plant).
    A. With other insects, such as wasps, lady bugs, and praying mantises.
        1. Add a praying mantis egg casing to the plant. Hang the praying mantis egg casing from a wire hook near the bottom of the plant, but not touching the soil. Out of the praying mantis egg case will come out many praying mantis. Keep them in the fridge so they don't hatch quickly.
    B. With natural oils and terpines:
        1. With rosemary oil and clove oil.
        2. With neem oil.
    C. With soap. For instance, to get rid of pincher bugs, spray your plant with a natural soap.
    D. With poison peptides.
19. Leave the root ball when you kill the plant. Potted plants have less of a tap root.
20. Seed Storage - keep seeds cool. If the oil on the outside is dried then the seed will dehydrate and die. It is possible to keep the seeds in the refrigerator.
21. Problems:
    A. If the plant grows too large, at the base, there is the potential for the base of the plant to break open a bit. Put some "tree sealer" in the crack. If it is not sealed, then bugs can get in there. Always tree seal cracks because bugs will get in otherwise.

6.7 Germination optimization

Using magnetics it is possible to optimize the germination and initial growth of seeds. North pole exposed seeds are desirable, whereas south pole exposed seeds turn bad easily. The best practice is to tape seeds on the north pole edge of a 2" by 2" by 1“ neodymium iron boron magnet. The seeds need only be positioned there for about 30-45 minutes, but it is possible to leave them there for longer. Even better results are possible if they are germinated over the top of the north pole of a magnet. (Davis, 1996 & 1979)

6.8 Harvest-ability

Someone can't (or at least, shouldn't) harvest a plant like dandelion greens where people are walking dogs (because dogs may have urinated on it). So, there are areas where dogs cannot go; there is separation of objects (e.g., people, animals, etc.) through structure where necessary in order to ensure cultivation plans are successful. That which cultivated foods and other resources need to be separated from may include wild animals, it may include animals within and around humans, and it may include separation from humans (e.g., so as not to contaminate a food or food process).

6.9 Locating

Firstly, different plants grow best in different locations. Location factors include, but may not be limited to:

1. Shade tolerance.
2. Nearness to syntropic plants and antagonistic plants.
3. Soil type.
4. Water amount.
5. Topographic slope amount.
6. Human requirements.

For example, olive trees work on slopes in some climates, and citrus trees planted on flattish areas dug into the soil (submerged planter beds) with large seasoned logs buried underneath (Hugel style) to sponge and hold water through the dry seasons.

6.10 Pollinating

A.k.a., Plant reproduction

There are two general types of plants in concern to reproduction via plant pollination:

1. Self-pollinated plants - are plants that use their own genes from their own pollen to produce the next generation.
2. Insect pollinated plants - are plants that use insects who accumulate pollen from a distance to produce the next generation. In the case of insect pollinated plants, genetic changes will occur more quickly, because the pollen comes from a distance, and with distance there is greater likelihood of having genetics that are highly similar. Insect pollination is a way of naturally introducing different genetic pollens from a distance.

6.11 Soil planting warnings

The following are two warnings for when planting plants in soil:

1. Do not leave the pot or basket or wire basket in place around the roots of a plant when planting in soil. If this is done it will girdle the roots of the plant.
2. Do not fill a hole dug for a plant with gravel as this will collect water and possibly drown the roots, along with preventing the roots from continuing to grow farther downward.
3. Do not plant trees around grass until they are at least a meter or so high, because otherwise the grass will choke out the young tree.
4. Stick a piece of bamboo next to the growing tree and attach the bamboo to the tree to help support it when young.

6.12 Plant growth parameters

Humans can measure all of these parameters (i.e., all plants need these elements to some degree in order to grow and survive):

1. Above ground.
   A. Space.
   B. Radiation (light).
      1. Photosynthetic radiation.
   C. Temperature.
   D. Humidity (correct atmospheric water composition)..
   E. CO2 (correct atmospheric gas composition).
   F. Wind (relative; appropriate air movement .conditions).
2. Below ground.
   A. Space.
   B. Nutrients.
   C. Water.
   D. Oxygen.
3. Time.

6.13 Nutrients for plants

Plants have the following nutrient requirements:

1. Organics - plant roots are capable of taking up complex organic molecules like amino acids directly; thus, bypassing the mineralization process.
2. Primary [macro] mineral nutrients - used in highest quantity and most essential for plant growth and development. The most common building blocks for the plant are:
   A. NPK - nitrogen (N), phosphorus (P), and potassium (K).
3. Secondary [macro] mineral nutrients - similar to primary in importance, but not quite as important as the primary nutrients.
   A. Calcium, magnesium, sulfur, etc.
4. Micro mineral nutrients - all of the mineral nutrients required in smaller quantities by the plants for growth and reproduction. Just because they are an input at low levels does not mean they are critical to plant survival.
   A. Silica, etc.
5. Synthetic nutrients (note: not a nutrient requirement)
   A. Phosphate (P) - Synthetic phosphate made from phosphoric acid.
   B. Potassium (K) - Synthetic potassium made from potassium hydroxide.

Nutrient solutions can be formulated separately for individual plants, or a common formula can be used for an area or region.

Fertilizer (nutrients) include:

1. Bacterial additives.
2. Fungal additives.
3. Mineral additives.
4. Organic waste additives (including compost and manure).
5. Air while mixing a liquid compost solution.
6. Worm additives.
7. Good quality soil.

Fertilizer solution sub-additives include:

1. Solid (dry) matter - often in powdered form applied either dry (atop or mixed into the growing medium) or in water/compost tea solution.
2. Liquid matter - generally, this is a formerly solid (dry) substance that has been solubilized in water. Or, for instance, it could be ocean water which has been processed to remove a large amount of the sodium chloride. Unnecessary shipping of water and
3. Water soluble nutrients - Under certain conditions, these can end up getting washed out and create environmental pollution; water soluble fertilizers leach into the groundwater, runs down the rivers and streams into the ocean and creates dead zones).
   A. Synthetic water soluble nutrients.
   B. Organic.
   C. Hybrid - some synthetic and some organic. transitioning fully to organics over time.
4. Soil amendments - General organics ancient forest - humus soil amendment - made through fungal

activity (versus thermal activity) - good to add to a compost tea. Helps create fungal dominated compost as opposed to bacterial dominated compost (made through thermal reactions). Letting wood chips rot and compost down, while inoculating them with some mycelia over several years will create a high fungal dominant compost.
5. Pasteurized soil - for indoor so that there are no insects or possible pathogens inside. Will have to add bacteria and fungus to this.

6.13.1 Fertilization of plants

Plants require nutrient inputs. The provision of nutrients to plants is called fertilization. Plants can be fertilized in the following ways:

1. By the decomposition of cellulose organic matter.
2. By the faecal matter and dead bodies of animals.
3. By a supplemental mixture of selectively chosen natural and/or synthetic ingredients.

Plants can be fertilized via multiple methods (a.k.a., fertilizer placement):

1. The natural method: Animals roaming the pasture will excrete and fertilize the soil with their excreta.
2. A fertilizer (natural / synthetic) may be directly added to the soil by spraying it on the soil or mixing it into the soil. It is possible to mix fertilizers into the top few inches of soil.
3. Through irrigation (a.k.a., fertigation): Animal dung and urine (or other fertilizers) may be collected, turned into a slurry, and then directed to crops through irrigation channels. Fertigation is the application of fertilizers to the soil through an irrigation system.

6.13.1.1 Compost tea supplement

It is possible to facilitate the vitality and nutrient availability by producing a aerated compost team containing some combination of the following:

1. Herbivore excrement and quality compost.
2. Insect frass (insect excrement).
3. Bat guano (bird excrement).
4. A blend of worm castings, composted wood chips, bio-char, trace ocean minerals, volcanic rock ash & fossilized kelp.
5. A blend of wood-chip humus, worm castings, bio-char & minerals.
6. A testable supplement of a: A blend of soluble kelp extract, soybean hydrolysate, kelp meal, nutritional yeast, soybean meal, humates, evaporated cane juice (sugar), alfalfa meal, humic acid with potash, rock phosphate, langbeinite, greensand, etc.
7. Ocean minerals.
8. Added minerals (e.g., silica, etc.).
9. Added carbon dioxide (CO_2).
10. Companion fungus spores.
11. Companion bacterial networks.

Compost tea depends on temperature and aeration. Compost tea can be made with leaves mixed in with water. It can be made with water and a bit of yucca mixed with water. And normal compost mixed with water.

6.13.2 Soil

Soil is made in two primary ways:

1. In a holistic cultivation system, soil is made by a plant (crop) and animal (livestock) cycle, wherein plants grow and feed animals that in turn fertilize the soil to grow more plants, and together, more soil is created.
2. In the sense of environmental decomposition, soil is also made by decomposing organisms (decomposers) that convert otherwise unusable organic matter into something useful [for other organisms]. The primary decomposers are fungi, mold, and bacteria. A compost pile is an example of this type of soil creation. There are two main classes of decomposing organism:
   A. **Recyclers** - Common recyclers found in nature include, but are not limited to: earthworms to ants, springtails, nematodes, etc. Some recyclers are recognized as food by different human cultures.
   B. **Decomposers** - Common decomposers found in nature include, but are not limited to: bacteria, fungi, lichen, etc. Some fungal decomposers are recognized as food (or medicine) by different human cultures.

Soil can be damaged by environmental factors. When soil is incapable of growing useful plants, it is often called, "dirt". The sun, for example, will oxidize exposed soil. The plough, which digs up and overturns soil will expose more soil to the sun and atmosphere, increasing its oxidation. It is recommended to keep the soil covered with plants or some other material to prevent oxidation by the sun and atmosphere. The soil can be covered by mulch or by growing biomass.

Common soil amendments include:

1. Compost
2. Minerals

In concern to minerals, it is important to do a soil test to determine what minerals are missing from, or are in an over-abundance in, the soil:

1. Magnesium - Excessive magnesium in the soil causes the existing calcium to become less and less available to the plants. Magnesium also tends to cause soils to lose their loft (fluffiness) and become stickier and compacted. Note, whereas calcium is easily up-taken by plants and livestock, the magnesium can stay behind and accumulate over time.
2. Lime - Adding lime year after year like this can, over time, actually chemically create clay soils.
3. Many other possibilities.

6.13.2.1 Mulching soil around plants

Mulch is biodegrading biomass placed around the base of a plant, and has the following benefits:

1. Keeps humidity.
2. Prevents other plants from growing.
3. Keeps temperature.
4. Protects from erosion when it rains.
5. Composts over time releasing nutrients.

Common mulch materials include, but are not limited to:

- Straw, leaves, twigs, trunks, wood chips.

6.13.2.2 Roots in the soil

Deeper root systems allow plants to draw more nutrients from the soil. They also help reduce field erosion.

6.13.2.3 Microbes in the soil

Microbes in the soil break down the solid organics, transforming them into salts which are then absorbed by the roots of plants. In other words, organics are salts by the time they break down to the point that they're absorbable by a plant. A prolific and healthy microbial population is also a necessary component of a soil grow.

High concentrations of inorganic salts tend to kill the microbes in the soil. That's why factory farmers have to let fields lay fallow every few crops - all the inorganic salts they pump into the soil renders it infertile, so they have to add organic material (compost/topsoil) and give the soil time to recover its microbial health and become fertile once again before they can sow it.

6.13.2.4 Decomposing manure

The decomposition of manure over a landscape will, when deposited sufficiently (and not in excess) will increase the fertility of the area..

6.13.2.5 Decomposing wood

Ramial wood (brush wood) is shoots and branches that are less than 2.5 inches in diameter (or less) with deciduous or hardwood trees. If soil is to be subjected to a lot of tillage apply about 10 tons over 1 acre as wood chips. Ramial wood can be added to compost piles. Add chips to soil alongside a perennial ground cover crop. Chipping and composting, or dispersing around the environment, planted with legumes, alphalpha. Dispersing chipped trees can change the ground layer and cause problems in the growth of some plants.

6.13.2.6 Decomposing organic matter (compost)

Compost is biodegraded and degrading organic matter. Composting material is decayed plant or food products mixed together in a [compost] pile and let to decompose before being spread on the landscape to help plants grow. The organic matter breaks down. Decomposition is a natural process occurring everywhere organic matter is present and no longer living. Everything rots. Composting is the procedural organization of organic decomposition. Composting is the intentional returning of organics back to the soil, and facilitating ecological sustainability and the organic fertility of land.

Compost is the decomposition of organic matter primarily via microorganisms without the development of pathogens. Composting involves three stages: preparation of the waste by adjusting its size, moisture content and carbon-nitrogen ratio; degradation of waste in pits, piles, vessels or vermi-composting; and finally preparing finished compost by curing and screening. Compost is optimized with reasonable percentages of carbohydrates, lipids, and proteins. However, there needs to be caution, because pathogens can infect and rodents can become a problem when there is too high of a lipid and/or protein quantity as a percentage of the whole compost. Some organic matter can take a long time to compost (e.g., seeds, such as the avocado seed pit). The process of decomposition in a pile of outdoor organic matter occurs best at specific temperature, light, and moisture levels.

> **NOTE:** *It is important to note that compost piles can turn "bad" and become breeding grounds for insects and harmful bacteria. This may occur when wrong materials (given conditions) are added to a compost pile.*

Some types of compost require more work than others:

1. Does the compost need to be rotated (turned over), aerated and mixed, and how often?
2. Does the compost need more dry cellulose matter, and how often?

In a habitat, it is possible for the composting service to happen in multiple ways:

1. It could happen on landscape near individuals' own dwellings.
2. It could happen on landscape at the cultivation system level, where habitat service teams collect and maintain compost piles.
3. It could happen at a mixture of the cultivation system level and the collective population inhabitant level, where either individuals

themselves and/or the cultivation habitat team collects and transports the compost to rotatable bins on walking paths in the habitat. The compost bins are rotated by those passing by, particularly children enjoy swinging on these bins.

There are different types of composting organism:

1. Vermicomposter (worm composter).
2. Compost with fungi.
3. Compost with microorganisms.
4. Compost with insects.
5. Most compost happens with a combination of the above.

Composting matter inputs may need to be separated and then added (in layers or mixed):

1. Primary nitrogen sources.
   A. Vegetables and fruits (i.e., kitchen scraps).
2. Primary carbon sources.
   A. Wood chips; coco coir; leaves (best to shred).
      1. Products: Compressed sawdust for animal bedding.

Hence, an optimal ratio of the two material sources is anywhere from:

- 50% nitrogen - 50% carbon to 90% nitrogen - 10% carbon. Regardless of ratio, mix the compost well.

  Note: Mixing is preferable to layering. The best bio-chemical reaction comes by mixing the materials and sources.

Technically, however, a ratio of the two is not required. Compost can be made, and bio-degradation (organic breakdown) will work with primarily nitrogen or primary carbon sources.

Composting outputs include (soil, then plant growth, then plants, then compost and manure, then anaerobic digestion to soil and biogas:

1. Soil.
2. Fertilizer (nutrient and biological organism source).
3. Biogas.

Methods of compost creation include:

1. Bury under soil.
2. Dig a hole in the ground and layer compost on top of it.
3. Form a circle or square with fencing or wood slats (in a manner similar to a raised garden wood slat bed), and fill up the inside space. This method can be combined with the hole method (#2, as in, dig a hole and then at the top form a circle or square with fencing or wood slats).
4. Put material in a compost tumbler bin, which is spun on a regular cycle to mix and aerate the compost.
5. Worm bin (a.k.a., vermiculture or vermicomposting) - worms break down the materials. Note, however, that worms prefer fruit and vegetable matter, and worms will not thrive as greatly on compost composed entirely of any combination of the following: grass clippings, leaves, shredded pruning's, etc. Note that worms don't generally like coffee grounds. If coffee grinds (or the like) are present, then fungi mycelium can be added to decompose the coffee. The coffee grounds are decomposed by the mushroom mycelium. The mycellium pre-digests the coffee grounds and makes it into a form that is easily composted.

Supplements for compost include:

1. Zeolites may be added as a mineral supplement, the zeolites will also absorb some of the amonia if the compost is producing amonia and other odors. They also hold and release water. Zeolites may reduce insect presence.
2. Pre-existing compost to inoculate with pre-existing microbes.
3. Rock dust - adds trace minerals to the compost.
4. Coffee grounds - adds minerals, moisture, and increases the rate of decomposition.
5. Worms. Be careful of mixing worms with zeolites. If the zeolite is in too high a ratio it could cut up and harm the worms.

The two types of liquid solution compost include:

1. **Compost extract** - in the field you add the microbes to the compost solution, then you agitate it, and the spray it quickly.
2. **Compost tea** - put all ingredients in a tank (maybe mix them, maybe not) and aerate it over time.

Compost tea is the creation of a liquid fertilization mixture that is aerated over a period of time before being given to plants. Compost tea (biologially active) involves putting compost (and other additives, or just additives) in water and letting it soak or aerate for a few hours. The process of adding water to a compost mixture and then aerating it is known as "brewing compost tea". Any compost can be turned into a tea (i.e., the addition of water) and brewed (i.e., the addition of air).

WARNING: *Do not use human or other mammal waste (as in, manure) in the composition of the tea.*

Compost tea ingredients generally include:

1. Water

2. Compost (if available)
3. Powder and liquid minerals
4. Bacteria
5. Hummus - is the aged, broken down further version of compost. Wood chip based hummus produces the fungal ecology.
6. Humic and/or fulvic acid
7. Worm castings - contains colony forming units of chitinase (enzyme that digests the exo-skeleton matter of insects, chitin), and colony forming units of cellulase (enzyme that dissolves the ... of powdery mildew spores). What the worms are fed matters. Produces a healthy bacterial ecology.

Additional ingredients include:

1. Organic components, for example:
   A. Worm castings, soluble sea-kelp powder, amino acids, kelp meal, legume meal, grass meal.
2. Mineral component
   A. Ocean minerals
      1. For example, minerals collected from a flood tide region after the area has been dehydrated. (e.g., Sea90 and Ocean Grown)
   B. Land minerals
      1. Mined minerals
      2. Soil minerals
      3. Volcanic ash

6.13.2.7 Overfeeding plants nutrients

It is difficult to overfeed in soil, but easy to overfeed in aquatic (e.g., hydroponic) environments. Overfeeding leads to:

1. Leaf "burn".
2. Stunted growth.
3. Poor finished product.

6.14 Plant specific characteristics

Different types of plants have different characteristics, the following are some unique characteristics to some categories of plants.

6.14.1 Seeds

Plants produce seeds in order to replicate and evolve their species.

6.14.2 Trees

Most trees take 2 to 5 years to become established, depending on site conditions and plant genetics. Trees take carbon dioxide out of the atmosphere and store it in long lived plant tissues. As plants live and die, and are consumed by animals, the organic matter is deposited (contributed) to the soil. Hence, woody plants can be used for carbon cycling purposes.

Trees can remain unpruned when young. When placed in an orchard a tree should never be pruned. Trees that begin their orchard lives unpruned never need to be pruned.

There are different pruning strategies that can be implemented:

1. **Challenging pruning:** typically involves limbing up tall timber trees or topping them at five meters. This is done either with chainsaws while off of the ground or with specialized machinery. Note that this type of pruning, with chainsaws in trees, is technical and dangerous.
2. **Cultivation under small tree system (STS):** is a tree pruning technique that keeps the height of the tree plants (e.g., a mango plant) at nearly nine feet, which will increase mango production about five times.
3. Many trees are "designed" by nature to be either burned down, blown down, or grazed by animals; because, they will sprout back from the roots. Hence, many trees can be cut off ~0.5m above the ground and the tree will sprout back from the stump.
4. It is sometimes optimal to harvest trees that are growing under a larger canopy, but will likely not survive because they are not shade-tolerant.

6.14.2.1 Mulberries

Mulberries have an interesting trait in that the pollen-bearing male flowers occur on one plant and the berry producing female flowers occur on another. This feature allows us to create a silvopasture system with both fodder production and berry production. Simply plant a row of mulberries with the plants spaced very close together, 3-5 feet, for example. Protect them from browsing for the first three or four years and by then the ones that produce male flowers and the ones that produce berries will become evident. In the late winter, the male plants at this age can be trimmed severely and the tops thrown to the cattle, sheep or goats. The female berry-producing plants can be left to grow tall and not allowed to be browsed. Cutting the male plants will not bother them but will instead stimulate them to send up numerous shoots, which will be delicious, tender and green for the livestock by mid-summer. With proper management a mulberry plant can be browsed twice each season without killing the plant. Over time the browsed mulberry row will develop a two-storey appearance with berry-producing trees up high (mulberries will grow to 25 feet or so) and forage-producing shrubs down low. (Shepard, 2013, p.132)

6.14.3 Grasses

It is relevant to note here that fertilizer may have to be applied (generally, one time) in order to get grass seeds started on soil that is low quality. Mowing and grazing grass stimulates it's growth and makes it a more dense pasture. There are annual grasses as well as perennial grasses.

6.15 Plant habitat-ecological functions and uses

Plants can perform different and useful ecological functions within the material habitat service system.

6.15.1 Soil nitrogen fixation

Many legume plants interact symbiotically with bacteria to "fix" nitrogen in the soil. In other words, legumes interact symbiotically with bacteria to "fix" nitrogen in the soil.

6.15.2 Indoor atmospheric purification

There are a number of plants that efficiently perform chemical synthesis at night when it is dark. The following are some of these plants. These plants clean the air to a small degree and provide oxygen at night (useful in bedrooms where humans are sleeping at night):

1. Money plant - removes formaldehyde. This one does most of the pollutant removal.
2. Areca palm - removes chemicals in the atmosphere.
3. Mother in laws tong - produces oxygen at night. While most plants take in carbon dioxide and release oxygen during the day, mother in law's tongue plant converts carbon dioxide to oxygen at night as well.
4. Cactus - an ideal plant for the bedroom because they produce more oxygen at night than non desert plants. This is because they use a mechanism called crassulacean acid metabolism which allows them to photosynthesize during the day while exchanging the oxygen for carbon dioxide at night.

By planning and using these plants effectively within a building it is possible to can reduce the amount of CO2 in the building. While most plants take away oxygen at night, these types of plants may give off oxygen at night. These plant also filters chemical pollutants, including but not limited to: formaldehyde, trichloroethylene, xylene, toluene, and benzene from the air.

6.16 Plant compounds

Plants contain a host of bio-chemical compounds, some of which are used by plants to defend themselves from predation and to compete in the wild. Plants produce a variety of chemicals in order to signal (within and between), and defend. Plant chemical communications and bio-chemical defense compounds include, but may not be limited to (Read: classification of plant defense compounds includes):

1. Nitrogen compounds.
   A. Alkaloids.
   B. Amines.
   C. Non-protein amino acids.
   D. Cyanogenic glycosides and glucosinolates.
2. Terpenes - compounds containing 1 or more isoprene units.
   A. Monoterpenes - (types of: pinene, myrcene, limonene, terpinene, p-cymene, etc.).
3. Terpenoids - oxygen-containing hydrocarbons; turpine compounds with an O functional group attached. (of the types: alcohols, aldehydes, esters, ether, epoxides, ketones, and phenols).
   A. Monoper-prenoids.
   B. Cartenoids (tetrater-prenoids).
4. Phenolic compounds (e.g., lignan).
   A. Simple phenols.
   B. Polyphenols.
   C. Flavanoids.
5. Terpenophenolic compounds - part terpenes and part phenols.
6. Proteins (amino acids, peptides; e.g., lectin, gluten, gliadin, etc.).
7. Other [signaling] acids
   A. Oxalic acid, phytic acid, salicylic acids, isothiocyanates (amino acid derivative as defense against pathogen attack), **phytosterols** (lipid fatty acids; e.g,., plant sterols and stanols).

6.16.2.1 Plant secondary [defense] compound influence/control

Note that is is possible for human cultivators of plants to increase or decrease the amount of these defense compounds in plants through two cultivation strategies:

1. **Plant defensification (environmental defense control)** - control of the environment of a plant to specifically expose it to environmental signals that trigger defense, such as insect bites and insect excrement frass (Read: insect frass). Plants, in general, will respond to insect predation.
2. **Food biofortification (environmental solid intake control)** - control the plants environment to give the plants an environment of appropriate nutrition from soil (minerals and decomposing organic matter), bacteria, and fungi.
3. **Atmosphere biofortification (environmental gas intake control)** - control of the plants environment to give the plants an environment of appropriate gas exchange. Plants respire (similar to humans, and they do need to respire, wherein, they take in oxygen and give off carbon dioxide (the same

way that animals do). Plants have a secondary respiration ability such that they can also perform photosynthesis, in which they take in carbon dioxide and give off oxygen. In any given 24-hour period, a thriving plant will give off a lot more oxygen than it consumes.

4. **Light control (electromagnetic exposure control)** - control of both the frequency and intensity of light, from that of sunlight, to that of electrical powered light emitting diode (LED) type.

6.17 *Plant pest and disease control*

A.k.a., Pest and disease control for plants.

There are mechanical and biological methods for dealing with plant pests and diseases. Animals can be extremely useful in this case. Many diseases and insect pests pass a part of their life-cycle in these dropped fruits and leaves, and then in the soil beneath them as they decompose. By rotating hogs, chickens, or turkeys at the right time it is possible to break that link in the life-cycle of the past and give the livestock a tasty protein bonus at the same time. In general, the first fruits and nuts that fall to the ground have some sort of insect larvae in them. Hogs can be introduced when fruit begins to first fall to the ground and they will consume all the fruit with the first hatch of pests that otherwise would have pupated; and instead, they are consumed.

NOTE: *Plants and animals do not (i.e., are not known to) share diseases. Animals, however, can pickup diseases from other animals. Insects can transmit diseases to plants.*

In cases where "plant and preserve" (versus "scatter and cull") strategy is used, it is often better not to wait until the plants have insects (pests); instead, develop a schedule that works to facilitate the plants don't acquire pests and diseases. Often waiting until problems/pests are seen it is too late to do something, or something is done in a panic. Panicking leads to hasty decisions that can lead to crop failure.

6.18 *Plant cultivation steps*

The cultivation of plants often involves the following steps:

1. Plant species selection.
2. Plant growth location (and medium) selection (a.k.a., field selection).
3. Preparation of medium - Selected area/field should be well prepared for germination and growth. The selected area should be fertile nature soil and better water, light facility.
4. Plant sowing/growing in the prepared field – Selected and prepared plant propagules are now grown in the field by maintaining specified distances. Plant to plant spacing is better for growth of the plants.
    A. Plant sowing - planting seeds or transplanting plants.
    B. Plant growing - giving the plant a conducive medium, nutrients, atmosphere and light to grow.
5. Plant harvesting.

Plant cultivation coordination involves:

1. Avoided plants – Plants that are to be avoided during cultivation should be removed from the field. This practice should be done in before and after the cultivation of the plants.
2. Water – Plant life requires a suitable amount of water.
3. Nutrients – Plant life requires nutrients.
4. Diseases – Diseases should be avoided and control measures enacted when it appears.
5. Protection of the cultivated plants - The plants should be protected from harmful biotic and abiotic factors. And, weak plants (with weak or non-adapted genetics) are let die and removed over time.
6. Harvesting – When to harvest must be determined.
7. Storage – Some harvested plants are stored after harvesting.

6.18.1 Plant protection from animals on pasture

Young plants need to be protected from herbivorous animals on pasture. It is a requirement to protect young trees and shrubs as they grow on pasture. Herbivorous animals will likely kill them if they are not protected as they grow (to sufficient size). Trees in particular must be protected on pasture as they grow.

There are different methods to protect trees and other plants:

1. Tree tube (for trees only) - a tube that fits around the growing trunk of a tree. They protect from cattle as long as the cattle are not allowed to eat the tree tubes.
2. Fencing:
    A. Individual fence cage around every single tree.
    B. High tensile electric around a grouping of trees.
    C. Note: If the cultivation system has goats and/ or sheep, then it may be preferable to use both individual fenced cages around every single tree and high tensile electric around groupings of these same trees.

6.19 Light for plants

Light provides photosynthetically active radiation (PAR) for plants. Plants absorb different colors of light during photosynthesis in different amounts in different stages of growth. With sufficient data, photosynthesis and plant growth can be predicted (along with other necessary inputs).

Light intensity is measured with (note: the units is different for plants and humans):

1. For plants: PAR - PAR is measured with a PAR meter in micromol (umol) - an expression of the amount of plant-usable light energy hitting a square meter during a single second. The PAR reading will aid in determining how far or near a grow light should be from the plants. 800-1000 PAR is often optimal. Often, a grow light should be positioned as close as possible to the plants without causing them radiant heat stress.
2. For humans: LUX.

Photosynthetically active radiation (PAR) is also known as:

1. Photosynthetic photon flux density (PPFD).
2. Photosynthetic photon flux (PPF).

Here, flux has two definitions:

1. **Per time.** Hence, in the case of photosynthesis it is measured in units of moles/seconds.

   PPFD; where, D = density

2. **Per area and time**, together. Hence, in the case of photosynthesis it is measured in units of moles/(m2 x s).

   PPF; where, no "D", as in PPFD, because the density is redundant)

   Note: Regardless of the definition, PPF and PPFD equal the same thing.

Light instrumentation for plants includes, but is not limited to:

1. PAR (PAR measurement instrument): Sensor options for measuring PAR. PAR sensors measure moles of photons. Note that to effectively determine PAR, the sensor must cover the full 400-700nm range, and not cut in past 400nm with a relative quantum response of 3.0 or cut off before 700nm with a relative quantum response of 3.0. The relative quantum response is the y axis on the graph below.
2. Spectrometer: A spectrometer (or spectroradiometer) is used to break up the light, which is then read by a series of detector arrays for each frequency providing the user with the frequency spectrum of the measured light.

Plants can use ultraviolet or infrared sections of the electromagnetic radiation spectrum for photosynthesis, but they generally do not. In general, photosynthesis occurs in chloroplasts where large protein complexes called photosystems I and II use light to excite electrons, evolve oxygen, pump protons across the thylakoid membrane (ultimately generating ATP), and reducing NADPH. Photosystem I and II absorb light to excite electrons, and do so optimally at 700nm and 680nm (red light). One photon excites one electron, and is the first step in photosynthesis.

To efficiently collect photons, the reaction centers of the photosystems are surrounded by proteins that contain light-absorbing molecules like chlorophyll and carotenoids. These are capable of absorbing higher-energy photons and channelling the energy to the photosystems. Thus, plants are able to use both red and blue light, while largely transmitting green (hence plants look green). Chlorophyll is the mechanism responsible for photosynthesis in plants. Notice that green does not get absorbed, and why is that? Plants are green, so they reflect green light. There are different types of chlorophyll.

The following are the sub-categories of possible light for plants:

1. Ultraviolet (UV) light: Each photon of ultraviolet electromagnetic radiation contains too much radiation for most biological systems. Its high energy drives electrons from molecules and breaks weak bonds. It is absorbed by oxygen in the forms O2 and O3 (ozone). The ozone layer of our atmosphere protects life on the planet from high levels of ultraviolet radiation. ultraviolet will outright kick the electron out of the molecule (which is in fact how it is defined). UV is in general just too destructive to be used to synthesize large molecules. There are a few exceptions.
2. Infrared (IR) light: Each photon of infrared electromagnetic radiation does not contain enough energy to do useful work in a biological system. Cells do absorb this radiation but it contains insufficient energy to excite electrons of molecules and is thus converted to heat. Infrared radiation is absorbed by water and by carbon dioxide in the atmosphere. IR is too weak.
3. Visible light: Each photon of visible light contains just enough energy to excite the electrons of molecules without causing damage to the cell." Visible light is just enough to move an electron up a

few energy levels;

4. Gamma radiation (a form of ionizing radiation): A gamma photon would knock several electrons off of the molecule and likely break bonds while doing it.
5. X-rays: When x-ray research was a very new field, some scientists did test if skin could get immune to x-rays, assuming it could just be like a sunburn but skin could also get a tan against x-rays. Cancerous results.

> **IMPORTANT:** *The sun peaks in wavelengths around the visible light spectrum. That is why our eyes adapted to see a range of wavelengths that we call visible light: it's the brightest and most useful range of wavelengths that are available to be seen.*

6.20 Mowing plants

A.k.a., Unwanted vegetation removal, weeding.

Both on and off pasture will requires the removal of vegetation. There are two ways to remove vegetation from the landscape:

1. **The ecological predator way**, which uses animals that eat vegetation (i.e., through specific herbivore species).
   A. Goats and sheep can be used to clean-up brush and unwanted vegetation. Goats and sheep can be mixed into a single mowing herd.
      1. Goats eat most types of brush and are hardy when it comes to what they can consume. They are more likely to eat leaves, twigs, and shrubs. Goats are natural browsers. Goats take care of trees and will reach up as high and graze the leaves of trees. Smaller goats will reach up about three feet and larger goats can reach up to five feet. Standing blocks can be positioned on the ground to allow the goats to reach higher.
         i. 30 goats can clear 0.4047 (1 acre) in 7-10 days.
         ii. 40 goats can clear 0.4047 (1 acre) in 3-5 days.
      2. Sheep are more for pasture and grass. Sheep are more picky and select specific grasses, clover, and broadleaf weeds.
2. **The electrical machine way**, which uses a machine that cuts and pulls (i.e., through a mower machine). There are mowing machines for all types of vegetation. Mowing machines can be manual and/or fully automated. All mowing machines require power, ultimately, electrical power.
3. **The manual way** by pulling plants out of the ground and using a knife to cut.

7 Animal cultivation specifics

A.k.a., Animal farming specifics, animal agriculture.

Animal cultivation is the act of caring for, raising, using, and harvesting animals. Pasture animals are essential to optimize soil regeneration and to provide essential food nutrition (and therein, flavor) for humans. The pasture animals are essential to optimize soil regeneration and to provide essential food nutrition for humans. Animals poop, pee and die on the land, feeding it.

The cultivation of animals includes the following human support functions:

1. For human nutrition.
2. For other animal nutrition (e.g., dogs).
3. For soil, and hence, for plants.
4. For human aesthetics.
5. For other material resources.
6. For decomposition and chemical cycling, and chemical repositioning on the landscape.

7.1 Human safety around animals

There are many contexts around animals that humans need to remain aware of their surroundings to remain safe. When cultivating, human safety should always be a priority.

For example,

1. When bulls are a permanent part of the herd, then humans need to be careful of their safety around the bulls.
2. When horses become frightened, they will kick their back legs, which can seriously injure or kill a human.
3. Some animals carry dangerous diseases.

7.2 Pasture grazing of animals

A.k.a., Animal pasture grazing. animal semi-wild (semi-domestic) caretaken grazing, natural foraging animals and diets.

In a caretaken pasture, animals may graze and forage safely for food, which includes searching for the food and consuming it. Caretaken means to create an intentional agriculture of plants, animals, and other species. Different animals may search for the same or different types of organisms to consume from the environment. Generally, animals on this landscape consume plants and/or insects for base nutrition -- pasture animals graze (eat) plants and/or insects primarily.

Different animal species have different grazing behaviors and may consume different species. In addition, different animals eat different forage species in different ways. (Undersander, 2021, 24)

7.2.1 Grazing land types

A.k.a., Pasture types, grazing lands.

Technical types of grazing lands include, but are not limited to:

1. Native range.
2. Seeded range (human seeded).
3. Riparian areas (wetlands or situated near the bank of a river).
4. Permanent pasture (irrigated/non-irrigated).
5. Grazed forest or woodlands.
6. Aftermath grazing of cropland or hayland.

Pasture lands classified by common bio-food area type include, but are not necessarily limited to:

1. Grass pastures (and legume pastures).
2. Tuber pastures.
3. Forest [pastures].
4. Orchard pastures (tree pastures, silvo pastures) - silvo meaning tree, and silvo pasture meaning trees in the pasture. Planting trees in the pasture. Young trees need to be protected because otherwise grazing animals will kill them by eating them or rubbing/scratching on them. The right species will protect the animals and provide shade, as well as food. If it is the right species it increases the productivity of the pasture. There are many types of silvo pasture. In particular, there is the
   A. Intensive silvo pasture - planting trees every square meter or closer, and interplanted with pasture grasses. Silvo pastures require a hydrated pasture and wont work on land with very little water.
5. Aquatic or riparian [pasture].

Note that all pasture types will be caretaken to some degree. For example, grass pastures will be planted with pasture grasses. The animals enter a pasture and graze them down to the found whereupon they are moved into another paddock. The grass repeats and you bring the animals in again.

7.3 Rotational animal grazing cultivation

A.k.a., Grazing system, rotational grazing coordination, rotational pasture coordination, rotational pasture control, rotational grazing, rotational pasture coordination, rotational pasture control, prescribed animal impact, grazing management, grazing coordination, paddock coordination, grazing management, grazing coordination, paddock coordination, Voisin grazing, Hohenheim grazing, intensive *grazing management, management intensive grazing, short duration grazing, Savory systems, strip grazing, controlled grazing, grazing control, and high-intensity, low-frequency grazing, holistic land grazing management (land recovery) - process of soil restoration and terraforming outward, polyphase farming, circular symbiotic farming, syntropy farming. Terraforming land recovery. (note: each prior term implies a slight difference in coordination)*

Prescribed animal impact refers to moving an appropriate number and of animals on land at the right times. To produce the quality and quantity of animals and animal forage from pastures, pastures must be coordinated (managed). Under rotational grazing, only one portion of pasture is grazed at a time, while the remainder of the pasture either:

1. Has another species of animal grazing on it, or
2. it rests.

To accomplish controlled grazing, a large meadow/pasture is subdivided into smaller areas (referred to as paddocks) and animals are moved from one paddock to another. Rotating different animals can improve the health of animals, the forage for animals, while also improving the soil. Intentionally rotating different animals through series of paddocks must be monitored. Resting grazed paddocks allows forage plants to renew energy reserves, rebuild vigor, deepen their root system, and give long-term protection. (Undersander, 2021, p1)

NOTE: "*To graze" means, to eat from a pasture or other natural ecological habitat.*

Rotational grazing is simply moving the animals from one paddock to another to allow the previously grazed paddock to recover. The time for this rest varies greatly, depending on local climatic conditions, time of the year, and forage in question but is often anywhere from three weeks to two months. In concern to regeneration/growth rate is affected by soil productivity and fertility levels, even within a pasture system, rest periods will vary. The best way to manage this situation is to have a flexible rotational scheme, moving animals to those paddocks that have reached their optimum available pasture. Animals should be kept off a particular paddock until it reaches its desired optimum available pasture.

Rotational species grazing is a biomimicry process that mirrors what occurs in nature -- the intent is to mimic nature in a way that provides for an abundance of human food. Here, the “farming” follows natural ecological cycles to the greatest extent possible within a human controlled environment. Grazing area are primarily a combination of pasture and orchard land that different animals are moved through in a particular order to mimic natural cycles, which builds the soil base and provides food. Regenerative and cyclical farming (a.k.a., symbiotic farming, etc.) necessitates the caretaking of other animals and the total ecology.

For rotational grazing to be successful, the timing of rotations must be adjusted to the growth stage of each animals forage. In some cases, rotational grazing involves simple and regular animal shifts from paddock to paddock based on rigid time scheduling. In other cases, rotational grazing involves animals being shifted from paddock to paddock based on a monitoring, analysis, and controlled (Read: collection, analysis, and response) to forage growth rates (and other cofounding factors). Note here that there is more benefit to reducing rigid schedules when there is better information about where to move each animal next given all the paddocks available. With sufficient soil, climate, and human coordination and material resources, most animals on meadows (pastures/paddocks) receive a substantial amount of their feed from the pasture. (Undersander, 2021, 2) Fundamentally, grazing animals ought to be graded where grass has appropriate conditions.

Rotational grazing has aesthetic and human environmental benefits. It is a quieter way of farming than mechanically harvested feed. It provides humans with activity spaces. It provides humans with differing aesthetic views and with food. Animal grazing systems are healthier than animals housed in confinement. Selected animals have their needs sufficiently met in the meadows. However, risks associated with exposure to sever weather and predators may be increased by grazing (depending on region). Animals redistribute minerals in the land through eating and excreting. Every day, the animals are eating, and excreting over the land, leading to a redistribution of minerals.

In a rotational grazing system, animals are moved around from paddock to paddock in order to mimic herds in nature, who moved from place to place away from predators and to areas with more fertile grazing land. This can now be done with fencing and planning.

Well-coordinated perennial pastures have several environmental advantages over tilled land (Undersander, 2021, p3):

1. Dramatic decrease in soil erosion potential.
2. Require fewer pesticides and fertilizer.
3. Decreases the amount of farmyard runoff.

The benefits to rotational grazing systems include:

1. Greater yield potential.
   A. This is a human [animal] life-support need from the cultivation system.
2. Higher quality and fertility pasture.
   A. This is an human life-support cultivation system need from the cultivation system.
3. Higher quality forage available.
   A. This is an animal life-support need from the cultivation system.
4. Higher quality life for farmed animals.
   A. This is an animal life-support cultivation system

design.
5. Decreased weed and erosion problems.
   A. This is an life-support cultivation system issue.
6. More uniform soil fertility.
   A. This is an life-support cultivation system issue.

Regular rotation of the animals has several benefits. First of all, it keeps them amused with plenty to eat which reduces their interest in escaping. It's healthy for them, allowing them to rotate out of spots where parasites might build up and boosting their immune system with different vegetation. And of course, it is how you get them to manage a large area of land in manageable chunks.

Pasture coordination is the controlled movement of cultivated animals to accomplish desired results in terms of animal, plant, land, or economic responses. Therein, grazing coordination is the controlled movement of grazing animals to accomplish desired results in terms of animal, plant, land, or economic responses. Note here that a paddock is general term for an enclosed meadow or cultivated grazing area. Each paddock provides food and water for the cultivated animals. Animals may be transferred from one paddock to another, and this process is known as pasture/paddock coordination (a.k.a., pasture management).

7.3.1 Animal rotation decisions

The decision to rotate an animal herb to a different paddock is an important one. Rotation decisions depend on the species an a number of ecosystem factors:

1. **Cattle**
   A. Cattle are usually introduced into a paddock when the grass grazing conditions are appropriate:
      1. 10 - 20 cm high, up to the point that the seed head is starting to emerge from the boot. If the grass goes beyond that then it may be preferential to make hay from the grass. In some cases, grass grows faster than it can be grazed, in such case, the grass can be collected for hay, let go to seed, or composted.

7.3.2 Animal rotation issues

The most common animal rotation concerns include:

1. What animals can make other animals sick in the rotation.
2. Is there sufficient food for animal in paddock.
3. Is there a separate area for winter food.
4. What are the right species (species combination) for the system.
5. What are the right quantities for the system.
6. How sensitive is the animal (e.g., sheep are sensitive to dogs, etc.).
7. Model out relationships between the species and the relationships between animals in rotation.

7.4 Pasture cultivated animal types

A.k.a., Paddock cultivated animals.

There are three primary types of pasture cultivated animals, each with unique needs (Undersander, 2021, 20):

1. **Ruminant animals** - such as cattle, goats, alpaca sheep, and sheep are "natural grazers" and have a rumen with microbes that break down most plant fibers. Ruminant animals usually obtain most of their nutrient and energy from grasses and other vegetation on the pasture. These animals may also graze the non-fiberous portions of plants, seeds, insects, and fruit. Some high producing animals may need to be fed supplementary feed to fulfill their production ability (e.g., dairy cows). Potential ruminant grazing animals that may be include in a pasture rotation, but may not be limited to (common names displayed):
   A. Cattle (bulls, oxens, cows).
   B. Sheep.
   C. Goats.
   D. Alpacas.
   E. Llamas.
   F. Camels.
   G. Bisons.
   H. Buffalos.
   I. Yaks.
2. **Pseudo-ruminant animals** - such as horses. These animals do not have a rumen, but do have appropriate microbes in an enlarged cecum, which digests some plant fiber. These animals often graze longer than true ruminants to get adequate nutrition. These animals also get nutrition from non-fibrous portions of plants, seeds, insects, and fruit. Potential pseudo-ruminant grazing animals that may be include in a pasture rotation, but may not be limited to (common names displayed):
   A. Horses.
   B. Donkeys.
   C. Mules.
3. **Non-ruminant animals** - such as pigs and poultry. These are non-ruminants with smaller digestive tracts within which relatively little fiber digestion occurs. These animals get nutrition from non-fibrous portions of plants, seeds, insects, and fruit. In pastures without sufficient additional food sources other than grass, these animals must be fed supplemental food. Potential non-ruminant

grazing animals that may be include in a pasture rotation, but may not be limited to (common names displayed):

A. Pigs.
B. Mangalitza (sheep-pig).
C. Chickens and roosters.
D. Ducks.
E. Guinea fowl.
F. Ostrich.
G. Rhea.
H. Emu.

Ruminant animals raised properly are part of a natural ecosystem cycle that sequester carbon into the soil, making the soil more fertile, increasing the biome quality of the soil, including mycorhyzal networks, that allow plants to grow more robustly, feeding the plants, and in turn, the animals. When the soil is provided with nutrients, animals I turn are provided with nutrients. The best way to increase soil carbon is by having plants and animals together on land, which requires proper regenerative grazing of ruminants on grassland and other ecosystems. The way to create healthy soil is with regenerative systems that include animals responsively.

NOTE: *Ruminants animals are upcycling non-human edible nutrients in their environment. Pasture materials that might otherwise be wasted are upcycled by livestock. Ruminant livestock in particular can make use of grass and other similar plants, where humans cannot. Hence, these animals upcycled non-human [edible] forage into a nutritious source of animal food and materials.*

Ideally forage production (or availability) should correspond with animal (livestock) needs. Animals need forage all year round. Providing an adequate supply from pasture alone requires a specific and flourishing pasture environment.

Supplemental feed can be made from grasses or other plants grown on some pastures during periods of rapid forage growth with little to no grazing. This vegetative matter can then be dried and stored for later supplemental use on grazing pastures.

INSIGHT: *Animals are essential for a healthy ecology.*

7.5 Animal ecological functions

A.k.a., Ecological niches.

Different animals will/can perform different ecological functions the support a healthy and flourishing ecology.

The following grazing (pasture and forest) animals have characteristics unique to their species (note: some animal species are combined below because their combination creates additional ecologically useful services):

1. **Goats (herbivorous):**
   A. Goats are primarily browsers and foragers of leaves and weeds. Goats will eat many types of nutritious plant materials, including grasses.
   B. Goats prefer the leaves and steps of woody plants over grass. Because of this preference, they can be used to clear land. Do not leave them in a pasture so long that they are forced to eat poisonous plants.
   C. Goats will often graze six feet high and eat the light-shading canopy before chewing the undesirable plant (from the cow's perspective) to the ground. This creates an opportunity for grass to fill in.
   D. Goats will eat different plants and grasses at different times of the year and will even vary their choices from morning to evening.
   E. Goats have the fastest metabolisms of all ruminants, except deer.
   F. Goats thrive best in dry climates. They can be raised in moderately wet climates if it is possible to provide an environment that minimizes their exposure to parasites.
   G. Goats generally find and eat the newest and most tender growth first. Hence, if they are forced to become pasture grazers, they are not going to eat the tall grasses and instead will go to ground level to get the youngest and (most tender) shoots, which is where the parasites are concentrated. After the parasite's eggs hatch, the parasite travel up the new blades of grass, and waits for goats to ingest them.
2. **Sheep (herbivorous):**
   A. Will eat more weed-like plants than goats or cattle.
   B. Sheep can eat a rotation of paddocks with different forage (for example):
      1. Wheat (grain).
      2. Oats and broadleaf rape.
      3. Turnips.
      4. Kentucky Bluegrass.
      5. Tall fescue.
      6. Orchardgrass.
      7. Bromegrass or timothy grass graze.
      8. Birdsfoot trefoil northern indiana.
      9. Lespedeza southern indiana.
      10. Sudangrass (35.56cm rows) graze when 30.48cm high.
3. **Sheep and goats (herbivorous)**
   A. Sheep and goats graze often bite plants close to the ground. This biting behavior combined with trampling can lead to erosion problems in some pastures.
   B. Ensure rocks are available for sheep and goats

so that you do not have to trim their hooves. Give them the environment to do it naturally themselves.

4. **Pigs (monogastrics):**
   A. Monogastrics can up-cycle [human] food scraps.
   B. Pigs can recycle some of the unused production from the farm/cultivation system. A certain number of the eggs from the hens won't pass inspection, and so feed them to the pigs. Pigs are forest animals, as opposed to pasture animals like cows and sheep. They do a great job of clearing out the scrubb so that it isn't a jungle right beyond the pasture land. Goats can go in the forest with the hogs. Hogs will eat the goat faeces. When they do that, they will pick up some nutrients. Heterosis. The pigs eating the faeces of the goats breaks the lifecycle of an internal parasite called barberpole worm. The eggs are passed through the goat, its faeces, it pupates in the earth, then the goats graze the grass and reinfect themselves. When the pigs eat the faeces they break the lifecycle.
   C. Pigs prefer to root, which makes them perfect choices for woodlands or marginal perimeter land. Most breeds can easily be trained to a solar electric fence charger that's located just a few inches off the ground (snout high). When pigs remain near fences pigs just love to root dirt and debris up to the fence, which could cause it to short out. When their paddock is cleared, simply create a new adjacent paddock for them, move them in, and (if you're so inclined) toss some seeds (turnip, pumpkin, squash) into the soil they just disturbed. Return them several months later; they'll harvest the crop for you, free of charge, and turn your seeds into pork.
   D. Some breeds of pigs can be effectively grazed along with the cows, sheep, and goats. I'm thinking mainly of the Large Black breed of pigs, and while they are effective grazers, like all pigs, they like (and need) to root. As a result, you'll likely end up with pastures ranging from lightly torn to having large wallows. In our experience, it's best to keep the pigs in the woods.
   E. Pigs are natural rooters and are likely to eat the entirety of plants, including leaves, stems, and particularly tubers, which they dig up and pull out of the ground. Note here that snout rings are sometimes applied to deter rooting behavior.
   F. Pigs like wooded areas. It is simple to have six pigs per half an acre given an appropriate passage. Pigs can be moved monthly to a new paddock, confined by a solar-charged electric fence and fed by hand. Smaller herds of pigs (e.g., one or two pigs), it is often optimal to locate the paddock adjacent to a garden for ease of growing, feeding human food waste, and monitoring.
5. **Goats, sheep and pigs (mix):**
   A. Goats and sheep, and to a lesser extent, pigs, can be "run" through wild nature surrounding the habitat service system as a fire mitigation strategy. They help eliminate excessive vegetative fuel in the area by eating invasive plant species and more woody material. In some circumstances, goats be used to eliminate noxious weeds. This will mitigate the risk of wildfire by reducing the amount of readily available flash fuel. The alternative to prevent growth is weeding, mowing, or chemical usage. Pigs, sheep, and goats can be used in border and woodland areas to reduce fuel loads, which, in turn, reduce wildfire risk.
6. **Poultry (fowl, including waterfowl):**
   A. Fowl will eat insects, worms, and plants. Because of this they can be used to weed, reduce parasites, and fertilize.
   B. Pulling a mobile hen house or moving a flock of ducks or geese a couple of days behind the herbivorous grazers allows hens to scratch through manure piles and harvest grubs (insect larvae). This provides them with much-needed (and free) protein, while drastically reducing the potential fly population.
   C. Turkeys can be grazed with the hens and they can be moved together as a flock. The turkeys tend to roost on top of the portable hen house at night, while the hens sleep inside.
   D. Chickens and turkeys act as the insect sanitation crew, ridding the pasture of grasshoppers, crickets, fire ants, and worms, which can wreak havoc in a pastures.
7. **Cattle (cows and bulls; herbivorous):**
   A. Cattle are raised and finished on specific grasses. Cattle are significant fertilizers of soil through the large consumption of grass the subsequent waste deposition made onto the soil.
8. **Insects (mixed):**
   A. **Bees.**
      1. Bees are essential for the pollination of some plants. Insects, such as bees, provide an essential ecosystem service, pollination.
      2. Bees concentrate sugars and produces wax as well as venom.
      3. A bee can fly up to five miles (kilometers) away

from their hive.

B. **Earthworms:**

1. Earthworms increase soil aeration, infiltration, structure, nutrient cycling, water movement, and plant growth. Earthworms are one of the major decomposers of organic matter. They get their nutrition from microorganisms that live on organic matter and in soil material.

7.1 Porcine up-scaling areas

A.k.a., Pork food scrap upscaling.

This is an area where food scraps from humans are fed to local pigs. The pigs can be free roaming (relative to the fencing), or enclosed within a fenced area proximal dwellings (where they are fed). In either case (small or large), the pigs can wander within a fenced area, and return to be fed/eat human waste food at particular location near dwellings.

7.1.3 Nutrient cycling in grazed pastures

Nutrient cycling in grazed pastures involves the following flow cycle:

1. Livestock and land - animals present on land.
2. Nutrient leaching -the downward movement of dissolved nutrients.
3. Livestock grazing - livestock consume resources and produces excreta and plant litter (etc.) as waste into the soil.
4. Nutrient uptake by plants and other organisms.
5. Human mineral addition and/or fertilization.

In this process, animals can upscale nutrients and make them available (or, more available) to humans.

7.1.4 Animal nutrition amendments (supplements)

Animals can be fed supplemental minerals and trace elements when they are missing from the landscape. These minerals and elements can also be added to the soil and specific plant genetics selected to uptake those elements and make them available to the animals.

7.1.5 Mineral toxicity for animals

Supplemental feeding of minerals and trace elements should be carefully monitored. Soil testing and forage testing is prudent in order to understand what your soil mineral levels actually are doing.

The following risks are present when feeding supplemental minerals.

1. Hogs can overdose on salt, whereas cattle love salt licks and are not likely to overdose.
2. Mineral supplements for cattle and hogs may include copper and be necessary for their health, but can be toxic for sheep.

7.1.6 Plant toxicity for animals

Some plants are toxic to some animals and not others. Plants do contain defense chemicals, and even animals that are primarily herbivorous need to take that into account when they are consuming plants.

> **NOTE:** *A toxin is a material in the wrong place, at the wrong dose, and/or at the wrong duration.*

7.1.7 Undesirable animals

> **NOTE:** *It is possible to unintentionally cultivate undesirable animals.*

There are wild animals that are undesired and undesirable around human habitat and pasture land.

1. Irritation and nuisance - animals that get into and tear apart trash, eat cultivated plants, as well as animals that may act aggressive, and possibly, create loud noises (e.g., wild dogs and cats, deer, etc.).
2. Disease spreaders - animals that will eat human waste, and leave their own waste, which could spread disease (e.g., rats, some herbivores, and animals with rabies, etc.).

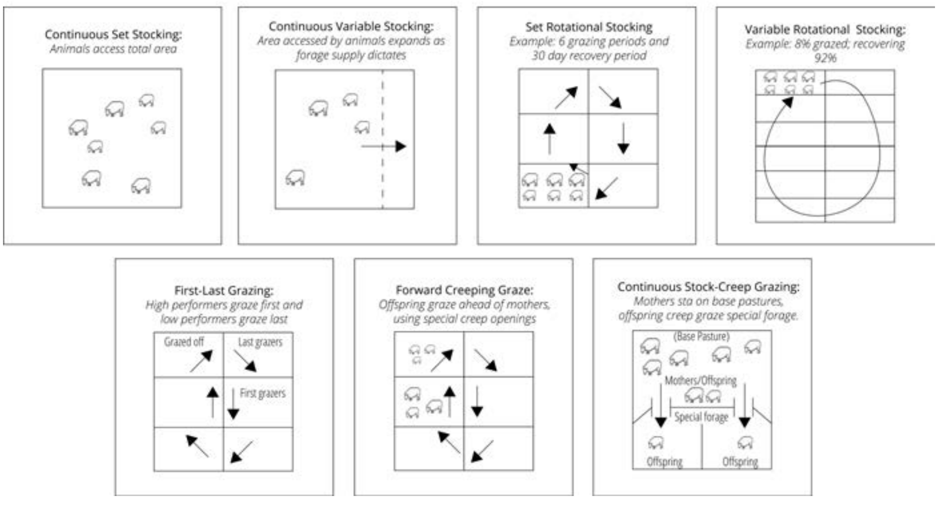

Figure 4. *Nutritional optimization stocking methods.*

3. Predators - animals that will kill and eat livestock (e.g., wild dogs, coyotes, panthers, etc).

7.1.7.1 Undesirable insects

Insects can harm, stress and irritate animals. Where there are animals and a caretaken ecology, there must be methods implemented from landscape pasture design to insect capturing control mechanisms. For instance, there are machines that can vacuum flies off cattle as they are moved between areas.

7.1.7.2 Techniques for deterring undesirable animals

Deterring undesirable animals can have many beneficial effects, including but not limited to:

1. Create a healthy and restorative landscape ecology.
2. Reduce recurring clean-up, damage, and repair.
3. Protect buildings and equipment from droppings.
4. Reduce health and safety risks.
5. Prevent the spread of diseases, such as lyme, west nife, e. coli, rabies, etc.
6. Maintain and increase aesthetics.
7. Maintain and optimize the ecology.

There are a variety of techniques that work in deterring and/or reducing incentives for undesirable wild animals in the habitat:

1. Physical barriers and fences - will prevent larger herbivorous animals and may prevent ground predators.
2. Human behavior:
    A. Do not leave rotting organic matter on the landscape.
    B. Do not leave organic matter in such a manner that animals habitat in it.
3. Material configuration:
    A. Create a habitat where wildlife does not interfere with human habitation and operation, for example:
        1. Do not have equipment, vehicles, and some architecture placed under trees where there is the probability of bird droppings.
4. Specific plants, and arrangement of plants.
5. Sonic area emitters:
    A. Ultrasonic emitters that cause an unpleasant feeling in animals.
    B. Aggressive sonic animal sounds - a system that uses customized aggressive animal sounds to ward off wild animals.

7.2 Pasture coordination

Standards for grazing coordination include:

1. US NRCS Conservation Practice 528: Managing the harvest of vegetation with grazing and/or browsing animals with the intent to achieve specific objectives. (*Prescribed grazing*, 2021)

The purpose of the pasture coordination is the following;

1. Sustain/maintain/improve:
    A. Land:
        1. Soil - desired soil composition, structure, and vigor.
        2. Species - desired species composition, structure and vigor.
    B. Food:
        1. Human food sources - quantity & quality of food for humans.
        2. Animal food sources - quantity & quality of forage for animals.
    C. Watershed:
        1. Watershed - surface and/or subsurface water quality/quantity; riparian/watershed function.
2. Improve range health:
    A. Human health.
    B. Plant health and resiliency.
    C. Water quality.
    D. Soil quality.
    E. Wildlife habitat.

To succeed, pasture coordination must account for at least the following variables:

1. The land:
    A. Pasture area positioning (paddocks) - pastures can be divided into paddocks. Those smaller paddocks can then be sub-divided also.
    B. Soil status - the positioning, quality, and characteristics of the soil.
    C. Water status - the positioning, quality, and characteristics of the available water.
    D. Consider the basic land resources - the types of elements, including water and mineral.
2. The animals:
    A. Design and calculate for:
        1. Animal performance (Read: animal fulfillment) - animal inputs and outputs for a fulfilled life.
        2. Plant productivity - plant inputs and outputs for productivity.
        3. Human requirements (Read: human viability) - human requirements for human fulfillment.
    B. Match animal type and nutrient needs to forage availability/quality in a matrix:
        1. Animal types
        2. Nutrient needs (animal requirements)
        3. Nutrient availability (quantity)
        4. Nutrient quality
3. The plants:

   A. Consider the basic plant resources - the types of plants (cool season/warm season, grasses, forbs and/or shrubs) and plant growth cycles.
4. Human coordination:
   A. Combination of coordination tools and techniques that promote distribution of livestock.

Pastures coordination is designed to meet human and cultivated animal food-associated requirements:

1. The pastures must ensure the appropriate quantity and quality of food for the animals.
2. The pastures must ensure the appropriate quantity and quality of food for the human population.

7.3 Grazing methods

A.k.a., Grazing systems.

Grazing methods include, but are not limited to the following high-level categories (some overlap and be combined):

1. **Continuous grazing (i.e., no rotation)** - Animals have unrestricted access to the entire pasture throughout the grazing period (season, year-long); the animals craze continuously on a single pasture.
   A. Advantages
      1. Least capital and coordination required.
      2. Allows greatest selectivity of forage quality.
      3. Generally - greater livestock production per unit area.
   B. Disadvantages
      1. Livestock have preferred areas of grazing.
      2. Non-uniform distribution of livestock and manure.
2. **Rotational deferred (a.k.a., deferred rotation)** - the skipping of pastures at specific times, for any reason.
   A. Multi-pasture, multi-herd systems.
   B. Each pasture receives period deferment (every 2-4 years).
   C. Design to maintain or improve range condition and forage productivity.
   D. Works best where considerable differences exist between palatability of plants and convenience of areas for grazing.
   E. Disadvantages:
      1. Individual animal performance less than continuous.
      2. Added requirements for fencing and fence maintenance.
3. **Rotational rest (a.k.a., rest rotation; rotational stocking)**
   A. Multi-pasture, multi-herd or multi-pasture, single herd.
   B. Uses recurring periods of grazing and rest among two or more pastures.
   C. Plans periodically receive a full growing season of rest for recovery.
   D. Disadvantages:
      1. Individual animal performance less.
      2. Added requirements for fencing and fence maintenance.
4. **Rotational high-intensity low-frequency (a.k.a., rotational management intensive grazing)**
   A. Multi-pasture, single herd.
   B. Stock density is high to extremely high.
   C. Length of grazing period is moderate to short, with a long rest period.
   D. Grazing units are not grazed the same time of year each year.
   E. Disadvantages:
      1. High fencing requirements.
      2. High levels of grazing intensity may reduce livestock performance.
      3. Soil compaction, grazing on wet soils.
5. **Rotational mob grazing (a.k.a., intensive rotational grazing, mob-stocked, mob grazing) -** refers to short-duration, high-intensity grazing of many cattle (or other livestock) on a small area of pasture (i.e., in a smaller paddock), moved several times a day, or every day or so, to new forage. This is short-duration, high-intensity grazing, which can be designed to improve pasture while increasing stocking rate.
   A. Multi-pasture, multi-herd or multi-pasture, single herd.
   B. Length of grazing is short.
      1. When a large number of animals are put in a small paddock for a very brief period of time (hours, or a day or two).
   C. Advantages
      1. More equal manure distribution.
      2. More uniform grazing.
      3. Higher number of animals per paddock.
6. **Leader-follower grazing systems** - one animal type is let into a paddock first. Once it has eaten its preferred foods in the first paddock, it is rotated into the next paddock. Then, the next type of animal is introduced to the first paddock (where the first animal just recently vacated). Leader-follower systems can often out-produce other types of grazing systems (for total animal weight gain), because each animal is allowed to eat its optimal foods first. In turn, each animal eats its preferred forage first. When it is done it is moved the next paddock, and the next livestock is let into the vacated paddock. The pasture is allowed sufficient

recovery time before the first (original) grazing animal is returned to the initial paddock.

7. **Silvopasture grazing system** (silvo-pasture, animal and tree systems, trees plus grazing livestock together) - the intentional combining of livestock production and woody plants. It is the intensive and intentional management of both the forage system and the woody crop. Silvo pasture is not the process of turning animals loose in the forest to graze. Instead, it is intensively managing an open canopy tree and forage system. This type of grazing models mirrors the grazing in natural savannah systems and other highly product ecosystems.

In the wild savannah's, herds of grazing animals are food for predators. Pressure from predators causes the grazing prey animals to form tight groupings, to graze fairly quickly on only their preferred foods, then move on to water and greener pastures. To mirror the wild flourishing savannahs, it is possible to implement a combined leader-follower, mob-stocked, silvopasture grazing systems. The concept of restoration agriculture uses this combination of practices to produce stable perennial plant and animal foods, while restoring soil and ecological services to a local area of land. A leader-follower, multi-species mob-stocked silvopasture can designed for growable biome.

In concern to the number of species being rotated for grazing, there are two categories:

1. **Single species rotation** - a single species is rotated around paddocks.
2. **Multi-species rotation** - multiple species are rotated around paddocks.

7.3.7.1 Manure rotation coordination

Shorter periods of occupation, small paddocks and ensure the correct amount of feed in the pasture for the animal duration. One of the many benefits of moving towards shorter periods of occupation in the paddocks, and getting each paddock correctly sized so there is the right amount of feed in there for the number of days they are there is that it moves toward an improved stocking density. The stocking density is the total number of animals in a specific paddock for a specific period of time. With improved stocking density the animals will more evenly distribute the manure in that paddock. Animals may still deposit more manure near shade and water sources, but overall the manure will be distributed more evenly. Smaller paddocks are easier to coordinate and to observe over time. The better the grazing coordination, the higher the stocking density, and the more likely animal manure deposition will be evenly dispersed across the pasture.

When animals are left for too long in a particular are their excessive deposit of manure is likely to damage the localized soil and plants. For example, when a chicken mobile hut is left too long on a particular ground the excess chicken manure can damage pasture vitality (temporarily) through excess nitrogen. When cattle cluster around the shade of a tree for too long a time, their manure can damage the tree.

"Manure scoring" is a method for monitoring and assessing livestock well-being in the grazing system. By observing the texture of the manure it is possible to get an idea of how effectively the paddocks are meeting their nutritional needs. In a cow, if the manure looks dry and balled up (and with a lot of non-digested fiber in it), then the pasture is probably over mature and has too much non-digestible fiber in them. In this case the animals may need to be supplemented or moved to a different area. In cows that graze very lush pastures, ones that are perhaps too high in protein and too low in fiber, then the manure will start to become soft and loose. And in extreme cases, the animals can get diahrea, cause by having too much protein and not enough fiber and energy.

A common manure coordination strategy is:

1. Drag manure out with a plough, or have it scratched by animals.
2. Mow the area with a mowing machine or other animals.
3. Let the paddock recover.

7.3.1 Multi-species rotational grazing (co-grazing)

A.k.a., Co-grazing, coordinated animal movement, coordinated multi-species movement, coordinated multi-species grazing.

It is possible to rotate multiple species around paddocks. The following is an example movement of animals. Cattle are the lead animal in the orchard; they mow by down by eating much of the grass. And, as they go the cattle fertilize the tress. They deposit their waste, and then, trample it into the ground to create fertile, carbon rich soil. Trampling from grazing animals incorporates their manure into the soil and crates hoof print pits that acts as miniature seed and water collection pits (basins or pockets). A few days after the cattle, the goats or sheep move through the same paddock. The goats eat the shrubbery that the cattle wouldn't necessarily eat. The goats also climb up and prune the bottom 6 feet of the trees. They also fertilize. Pigs are run through as left-over waste consumers. Then we send through the chickens in a mobile chicken coup. The chickens also fertilize the soil and eat all the bugs that hatch from the manure of the first two ruminants that went through. Chickens come in after the pigs have dug up big clumps of grass. They "cleaning out" the area and fertilize with their high manure. The chickens will eat some of the parasites from the sheep that are there (if there are any there), which makes the sheep healthier because it cuts down on the parasite load. If animals are kept on the same piece of land all the time, then one sick sheep will inoculate all the sheep, and make for poor soil. By moving them around their parasite load is reduced, and the consequence is healthier soil and healthier animals. The interaction of multiple species together, either in the same or separately rotated paddocks can create a healthier ecology and more productive cultivation system.

It is possible to coordinate the movement of i 4 different animal species through an area, and as a result, acquire multiple cultivations, build up our soil base, and have the opportunity to play a role in the well-being of other symbiotic species, while giving humans a picturesque environment to enjoy in a variety of fashions.

Pastures may be used for herbivores and onmivores. When a herbivore is on a piece of pasture, they are walking around, and their hoofprints make indentations, which helps the land the hold water. The herbivores are chewing on the grass, which stimulates grass growth (including root growth). When grass is cut it grows. The grass and other plants are chewed by the herbivore, digested, and excreted with a host of microbes onto the soil. The herbivore then spread and compact their manure into the ground. Animals also poop on the ground and their manuŕe has microbes and other nutrients that build the bio-ecological network of the soil (i.e., build the soil). When perennials are allowed to continue growing, while being grazed occassionally, their roots grow deeper. Deep roots help with water retention in the soil. The animals improve the pasture through their grazing, rooting and fertilizing.

When grazing more than one species, it is best to graze the most selective ("picky") grazers first, and follow with the less selective grazers (e.g., start with cattle or horses and follow with sheep or goats). (Undersander, 2021, 24)

7.4 Grazing groups

It is often optimal to divide animals into different groups based on nutritional requirements for desired performance and condition of the landscape. Animals requiring the highest level of nutrition get the highest quality forage, while saving the lowest quality forage for the animals with lower nutritional requirements.

There are two ways to use forage to meet animal needs together:

1. Graze more than one group on the same paddock sequentially.
   A. All the animals could be introduced together.
   B. Introduction of different species into a pasture can be a staged process where high producers are introduced first (to consume the highest quality forage), animals with lower nutritional needs graze second, followed by the animals with only maintenance requirements.
2. Graze different groups in separate paddocks. Different species are in different paddocks. If there are poor quality pastures, then it is often useful to let the animals with lower nutritional needs graze them.

7.5 Cultivating pasture animals

A.k.a., Animal stewardship.

Animal stewardship involves the caretaking and use of other animals.

7.5.1 Animal life requirements

The seven cardinal parameters for growing animals:

1. Boundary transference environment:
   A. Light
   B. Temperature
   C. Humidity
   D. Wind (air velocity)
   E. Atmospheric composition with at least O_2
   F. Water
   G. Nutrients
   H. Land

Non-human animals have a set of [life-support] needs similar to those of humans:

1. Animals need appropriate **light**.
2. Animals need appropriate **climates**.
3. Animals need appropriate **shelter**.
4. Animals need appropriate **food**.
5. Animals need appropriate **water**.
6. Human (and other) animals need appropriate **social connection and fulfillment structures**.

7.5.2 Animal water needs

Although animals on sufficiently abundant pasture can get the majority of their water from forage (which is 80-90% water), an appropriate supply of clean water is essential in a grazing system, especially on hot sunny days. Some animals need more drinkable water, some need less, and some need ponds of water. Drinkable water can be distributed across a pasture by means of either gravity or pumping. A passive water system can be gravity fed from a pond at a higher elevation. These ponds, and water sources in general, should not have manure in them. For herbivores, it is generally important to have a water infrastructure on each paddock so that the herbivores can drink each day.

In general, clean water should be available to animals at all times, and watering tanks or troughs should be emptied and purged between species. Or, there should be sufficient water bodies or water flows nearby. Water distribution points should be appropriately placed and of appropriate size for the herd of animals.

Table 46. *Averaged daily water requirements of grazing animals. Note that animal water needs will be greater on hot, dry, and sunny days, or when grazing forage is dry. Needs will be less on cool, rainy days and/or when grazing on lush forage. Water needs will also be different depending on reproductive phase.*

Animal	Liters per day
Beef cows	56 - 76
Dairy cows	76 - 114
Yearling cattle	37 - 57
Sheep	7 - 11
Horses	37 - 57
Goat	7 - 11
Pigs	1.8 - 5.6
Chickens	~.4
Ducks	1
Geese	1.6 - 3.9

The placement of water in a field is essential. For cattle, ideally, water should be available within about 243 meters of the maxim distance from which animals might have to travel in a grazing system. Missouri research indicates that cattle, for instance, will not graze much further away from water than this. Performance per animal may be reduced when cattle are forced to travel more than 243 meters to access water. For many animal species, consuming water is a social function in that it requires movement of the whole herd. (Undersander, 2021, 22)

When considering watering equipment, determine the proper size of the watering tank based on the grazing system used and animal type. One of the best references here is USA NRCS FOTG Conservation Practice Standard – Watering Facility. (No.) CODE 614. [nrcs.usda.gov].

It is important to locate watering tanks away from waters surface water sources will help reduce contamination. Avoid sloping terrain to prevent erosion and run-off. Select a level and well-drained site to minimize trampling of vegetation and creation of a muddy area. (Hawkins, 2021)

Generally, it is optimal to have water available for animals in all paddocks. In some cases, it is better to siphon water to the animals, rather than brining them to the source of the water. Channelling water reduces disease and parasite problems and preserves water quality. (Undersander, 2021, 22) There are both moveable and stationary solar and battery powered pasture-based water pumps.

Drought is a period of little water (i.e., an excessive climactic incident). During periods of drought it is often necessary to take remedial action to ensure that forage lasts longer (or, as long as possible). Rest between grazing becomes more crucial as drought stress increases. In some cases, it is possible to set land aside to be grazed only during a drought. Such land should be populated by extremely drought tolerange forage (e.g., warm-season grasses). (Undersander, 2021, 30)

7.5.3 Animal shelter needs

Some animals are more tolerant to both the heat and the cold. Other animals are more likely to need shelter when it becomes too cold or too hot. Sheep are more tolerant than other animals to both the heat and cold. On hot days, most animals need some form of shade and a source of water. On very cold days, most animals will require some form of shelter keep temperatures warmer.

7.5.4 Animal food needs

Primary animal food-associated life requirements:

1. Nutritional needs at various stages of lifecycle.
2. Forage-animal balance: match forage available with the needs of the [grazing] animals.

How much forage is consumed per animal depends on a variety of factors. Animal feeding species type, quality, and quantity based on the animal characteristics of:

1. The species of animal?
2. The size of the animals?
3. The reproductive stage of the animals?
4. The animal density (density of herd)?
5. The amount of forage available?
6. The quantity of forage available?
7. Calculate: energy required by animal(s)?
8. Calculate: energy intake?
9. Determine: Is there dietary sufficiency?

The amount of forage available influences consumption. If forage is tall, for example, large amounts may be wasted because of trampling. When forage is too short or thin, animal intake will decline and animal performance will suffer.

Animal dietary selection includes three characteristics:

1. **Species** for consumption by animal. What is the specific specie or species that the animal will consume? E.g., grass for ruminant animals, etc.

   Animals consume species either alive or dead:

   A. **Live** [species for consumption by animal]. Will the animal will consume the specie alive, is this preferred (and when), and if so, how much is consumed?
      1. Biomass composition.

   B. **Dead** [species for consumption by animal]. Will the animal will consume the specie dead, is this

preferred (and when), and if so, how much is consumed?
1. Biomass composition (e.g., dry matter, DM).

Many animal species prefer not to graze during the hottest part of the day. Often, the heaviest grazing periods occur in the morning and after sunrise for two or three hours. During hot days, animals need abundant water and may benefit from being provided with shade. (Undersander, 2021, 23)

Animals that consume plants will often selectively graze certain plants parts over others. Rumanent animals eat from the top down, taking the youngest, most nutritious leaves first, leaving the less nutritious stems for later. Smaller mouthed animals, such as sheep and goats, can graze more selectively than larger ones like cattle.

7.5.4.1 Species-specific diets

A.k.a., Species-appropriate diet.

Animals species consume a species-specific diet:

1. Cattle consume:
   A. Plant matter - pasture grasses (and related plants), along with relatively small amounts of grain when the grass is going to seed.
   B. Other organisms - insects, and small mammals rarely.
2. Sheep consume:
   A. Plant matter - pasture grasses and plants (including woody material).
   B. Other organisms - small mammals and insects.
3. Goats consume:
   A. Plant matter - pasture grasses and plants (including woody material), fruit.
   B. Other organisms - small mammals and insects.
4. Pigs and hogs:
   A. Consume:
      1. Plant matter - particularly tubers and roots, leaves, and fruit.
      2. Small mammals, newborn of larger mammals, eggs and young of ground-nesting birds.
      3. Invertebrates - such as worms, insects, and insect larvae, crayfish.
      4. Reptiles.
      5. Dairy.
      6. Human scrapes.
   B. Some basic principles of pig grazing include:
      1. More pigs on fewer square feet root up the soil over a shorter time.
      2. Fewer pigs rotated faster graze rather than root.
      3. Soft soil (e.g., spring, rain, etc) will get rooted more.
      4. Larger pigs root deeper than smaller pigs.
      5. Pigs often require supplemental feed on pasture, unless the pig is:
         i. A breed of pig that is nearly feral and B) lots of land for them to roam. If you do choose to feed them, I recommend hand feeding daily in a trough and not using a metal feeder with a flap lid. Those metal feeders produce a loud and unmistakable noise that will be heard far away as the pigs clank the lid up and down through the day and night, calling attention to your bacon on the hoof.
5. Fowl and waterfowl
   A. Foul
      1. Plant matter - grasses and other plants, and seeds.
      2. Other animals - insects, worms, snails, amphibians, fish, eggs, small mammals and reptiles.
   B. Waterfowl - mostly live on aquatic or near-aquatic organisms:
      1. Plant matter - pond weed, seeds, grasses and other plants.
      2. Other animals - insects, worms, snails, amphibians, and crustaceans, fish and eggs.

How much land and what conditions of the land are required for one animal of a species, and are required for the whole herd:

1. Stage of development
   A. Amount of food (quantity and quality) for health.

When pastures do not provide sufficient food, supplemental food (nutrition) can be provided. Supplements should be formulated to complement the forage growing on the pasture.

7.5.4.2 Winter-specific diets

There are locations where year-long grazing is possible, and locations where grazing is only possible during certain months of the year, and either the animals need to be housed from the elements and fed fodder, or they may still forage the land, but require significant additional fodder. Feeding additional good quality grass hay is the simplest way to ensure grass-eating herbivores will meet their nutritional requirements in the cold. Fodder is food for the winter, when it is dry and/or during times when there is not foraging food. Fodder is stocked material nutrition (a.k.a., food) for animals.

Hay is dried grass taken from grass that has become too mature for cattle to desire grazing. There are several main types of hay:

1. **Dry hay** - is simply grass that is cut and dried to use as animal fodder. The moisture content of dry

hay is not more than 12%. With this technique, the hay is mechanically cut and repositioned into a cylindrical form.

2. **Baleage** - is moist hay that is wrapped in a single use plastic bale (looks round). It is simply hay that is too moist to store safely as dry hay so it is wrapped or otherwise sealed in plastic. Baleage can be fermented as individual bales or in a tube/inline. This technique uses single use plastic. With this technique, the hay is mechanically cut, repositioned into a cylindrical form, and then covered with plastic.
3. **Silage** - is cut and dried grass that is fermented and stored in a silo before being used as food. Silage is fermented with 40-60% moisture. With this technique the hay is cut and dumped into a storage tank/silo.

NOTE: *Fermentation preserves and makes nutrients in the grass (such as sugars and proteins) more bioavailable.*

7.5.5 Animals grazing on plants

Grazing is not "bad" for pasture plants. Pasture plants have special ways to cope with grazing. Some plants are more adapted to continuous grazing, and some are not. Taller growing forages usually die under continuous grazing since most of the leaves can be grazed off. Taller growing forages needs [more] rest between grazings to survive on a pasture. If allowed to grow tall, taller forages will block the sunlight of shorter forages and plants.

There are two types of plants that may be present in a pasture:

1. Perennials - return every year (keep living). Perennials need to be planted once. Perennials are mostly ever growing. Perennial plants photosynthesize earlier in the spring and later in the fall than annual plants.
2. Annuals - die at the end of a year. Annuals need to be planted annually. Annual plants photosynthesize later in the spring and earlier in the fall than perennial plants.

For most perennial grasses, for every foot above ground there are roughly two feet of roots below ground, and those root systems. These root systems do a number line f things. They infiltrate and break up the ground so that when it rains the ground can hold more water, and the capillary action of the root system can sequester water.

There are many plant species and parts of plants that can be grazed on a landscape by pastured animals. Animals may graze on the following types and parts of plants:

1. Grasses and legumes (type) - Grasses are generally herbaceous plants (i.e., lack woody stems). Grass means any plant of the family poaceae, characterized by leaves that arise from nodes in the stem and leaf bases that wrap around the stem, especially those grown as ground cover rather than for grain.
2. Herbs (type) - Herbs are a short-sized plant with soft, green, delicate stem without the woody tissues. They normally complete their life cycle within one or two seasons. Herb means any green, leafy plant, or parts thereof, used to flavour or season food.
3. Shrubs (type) - Shrubs are medium-sized, woody plants taller than herbs and shorter than a tree. These plants generally have a woody stem.
4. Trees (type) - Trees are big and tall plants. They have very thick, woody and hard stems called the trunk.
5. Climbers (type) - Climbers are the plants with long, week and very thin green stem, which use external support to grow and carry their weight. (e.g., beans, cucumber, gourd, jasmine, money plant, etc.).
6. Creepers (type) - Creepers mainly refer to those plants which have a weak stem and are extended horizontally along with the soil on the ground as they cannot stand upright. (e.g., pumpkin, passionflower, sweet potato, etc.).
7. Leaves (part).
8. Fruit (part).
9. Flowers (part).
10. Root or tuber (part).

7.5.5.1 Plant rest periods

Optimal growing conditions for plant will decrease the rest period required for a pasture. Plants under environmental stress (drought, extreme weather, poor soil fertility, etc.) will require longer rest periods. Rest periods for plants are closely related to seasonal conditions:

1. Legumes generally need rest periods of 3 to 4 weeks throughout the season.
2. Cool-season grasses need as little as 2 weeks of rest during cool weather and 5 to 7 weeks during hot weather.
3. Grass-legume mixes should be grazed when the grass reaches an optimal height (i.e., yield to quality).
4. Warm-season grasses need to rest for 5 to 6 weeks during cool weather and about 3 weeks during hot weather.

Short grazing periods is often best, because livestock graze selectively and will eat the highest quality forage when first accessing a paddock. The animals will be forced to eat lower quality feed each day. Shorter grazing periods are more likely to provide more uniform forage consumption. It is important to note here that some species do not benefit greatly from rapid rotations. Other species can be moved to a new pasture 2 to 6 days (in general). (Undersander, 2021, 27)

Often, the longer a pasture is grazed, the longer the pasture needs to rest. The higher the plant nub, the more quickly the plant will be able to recover after grazing. In principle it is appropriate to leave 4 to inches of nub for cool-season grasses and legumes, and 4 to 8 inches for warm season grasses.

The pasture soil and plants can be collected should occasionally and tested for nitrate levels. Grazing pastures with plants that are known to concentrate nitrates should be avoided, introduced slowly, or have supplemental feed available, especially after a drought (which, would have concentrated nitrates even more). (Undersander, 2021, 38)

7.5.5.1 Grass plant grazing

Grazed grass growth and life requirements include:

1. Appropriate soil and atmospheric conditions.
2. Leaf area
3. Growing points.
4. Moisture for growth/regrowth.
5. Opportunity for regrowth.
6. Frequency and intensity of defoliations (how often and much?).
7. Timing of Grazing (when?).

The effect of defoliation of grass by grazing animals includes:

1. Defoliation above growing points of leaf blade causes the following:
    A. Growth continues provided water, sunlight and proper temperatures are present.
    B. Photosynthesis produces carbohydrates. Some used for new cells and cell enlargement. Some becomes soluble carbohydrate reserves and plant health not affected.
2. Defoliation below terminal growing point causes the following:
    A. Growth stops.
    B. Few carbohydrates produced or stored.
    C. New growth from dormant basal buds.
        1. Uses soluble carbohydrate pools stored in the root crown and/or lower part of stems.
            i. Repeated defoliation below growing points, during the rapid growth phase, across years, reduces and can eliminate stored energy reserves, which kills tillers and plants.

Types of grasses include, but are not limited to:

1. Elongated tillers.
2. Unelongated tillers.
3. Short grass - more grazing tolerant.
4. Long grass - often less grazing tolerant.
5. Root growth - Grass root growth – 20-50% of roots must be replaced annually (Dietz, 1988).

There are four general grass forage growth patterns include:

1. Cool-season grasses - most productive in the spring and fall, but go through a mid-summer decrease in production.
2. Legumes - growth starts later in the spring than cool-season grasses. Many withstand heat and drought better an cool-season grasses.
3. Warm-season grasses - need warm soils for germination and thrive on mid-summer heat the slows the growth of most other species.
4. Other alternative forages - such as annual grains (oats, winder rye, and winter wheat) and crop residue (e.g., corn stalks) can be grazed in the early spring and/or late fall.

Continuous grazing grass types includes but are not limited to:

1. Kentucky bluegrass
2. White clover
3. Many prostrate "weeds" (where low growing leaves may escape being grazed off)

> **NOTE:** *A tiller is an additional shoot (often forming from buds below the soil surface).*

Grasses that may be grazed more aggressively include grasses that tiller early and produce heads profusely throughout the year. The stems of these grasses do not elongate after initial heading (grazing of the head of the grass). Examples of these grasses include:

1. Tall fescue.
2. Perennial ryegrass.
3. Kentucky bluegrass.

Grasses that should not be grazed until new tillers are visible at the base of the plant usually have stems that elongate after heading, lifting the potential growing points above the soil surface where they may be removed by grazing. These grasses must be coordinated differently. Examples of these grasses include:

1. Bromegrass.
2. Timothy grass.

7.5.5.2 Grasses and legumes

Characteristic of forage grasses and legumes can be input into a table where each row is a type of grass or legume and the subsequent columns are A through H:

1. Grass/legume type is either excellent, good, fair, or poor for the following characteristics:
   A. Regrowth potential.
   B. Legume compatibility.
   C. Winter hardness.
   D. Ease of establishment.
   E. Drought tolerance.
   F. Flooding tolerance.
   G. Grazing tolerance.
   H. Species persistence.

7.5.5.3 Legume plant grazing

Unlike grasses, legumes flower in the seeding year and several times annually every year thereafter. Like grasses, grazing or harvesting top growth encourages development of new tillers at the crown. Legumes continue to branch and enlarge, and eventually flower. (Undersander, 2021, 7)

> **NOTE:** *Many pastures use grass and legume mixtures.*

7.5.5.4 Plant species pasture control

Pastures should be coordinated so that they contain useful plants. A pasture design should avoid the inclusion of plants that the livestock avoid eating, that have low nutritive value or are poisonous. Good rotational grazing systems will tend to keep most avoided plants out of the pasture. Note here that grazing coordination alone will not normally correct pre-existing plant problems. (Undersander, 2021, 8) There are different regional control regulations and recommendations for getting rid of plants.

Common control procedures include, but are not limited to:

1. Animal movement.
2. Cleaning equipment.
3. Mechanical uprooting (dug up).
4. Controlled fire (controlled burn).
5. Herbicide chemical (chemical death).
6. Graze frequently.

> *Note that different procedures will be required for different plant species.*

Avoided plants are generally more of a problem in overgrazed, infertile pastures, rather than, in fertile and well-coordinated pastures). To prevent the spread of avoided plants, avoid spreading manure contaminated with the seeds of these plants. Clean equipment after working in a pasture containing those plants. Repeated grazing, mowing, clippings, and mechanical uprooting can diminish unwanted plant populations. Tillage can also be used to suppress avoided plants by covering them with it. In concern to herbicides, spot spraying is often the appropriate treatment. Herbicide usage must include the correct identification of the plant, and should not be applied until animals have left the paddock. The paddock should not be grazed again until treated areas how followed label restrictions. (Undersander, 2021, 9)

7.5.5.5 Plant life requirements

The nine cardinal parameters for growing plants:

1. Foliar zone environment parameters:
   A. Light.
   B. Temperature.
   C. Humidity.
   D. Wind (air velocity).
   E. CO_2.
2. Root zone environment parameters:
   A. Temperature (root-zone).
   B. Water.
   C. Oxygen.
   D. Nutrients.

There are three general categories of plant nutrients:

1. Sunlight (EM radiation).
2. Mineral nutrients.
   A. 13 mineral nutrients (at least).
   B. Macro nutrients.
      1. Primary.
      2. Secondary.
   C. Micro nutrients.
3. Non-mineral nutrients.
   A. Hydrogen, carbon, and oxygen found in the air and water.
   B. Bacterial outputs.

7.5.5.6 Plant mono-agriculture

Growing acres of mono-agriculture will deny that land to the animals that would otherwise have lived, and eaten, and thrived there.

7.5.5.7 Plant seeding methods

There are a number of different approaches for seeding pastures:

1. No-till or reduced tilage - Seeds are drilled into existing sod.
2. Frost seeding - The seed is spread onto pasture in late winter or early spring (during or just after snowmelt). Moving animals across the seeding area immediately after thaw may help to sow the seed and improve its growing condition.
3. Grazing coordination - using livestock to seed. Using

livestock to do the seeding in areas not accessible or not preferable by technical equipment. The animals eat the seed, and some of it is available in manure for generation. For areas that are available for equipment, it is possible to mix seed with manure before spreading. Seed can be mixed directly with manure before its spread on pastures.
4. Tiling based seeding (a.k.a., conventional seeding) - this method exposes most of the soil by digging up soil and forming small trenches.

7.5.5.8 Soil fertility

To maintain healthy pastures, coordination must ensure that soil nutrients are returned to the soil at the same rate they are removed. Once soil nutrient levels are optimal, nutrient cycles naturally. Grazing animals normally return 60 to 80 % of available pasture nutrients (with extreta). Even in an optimal environment, some additional fertilization will probably be required or would at least provided added benefit. However, in some cases, supplemental feed can provide too many nutrients to a specific animal (e.g., pastures rotationally grazed by dairy cows receiving high levels of supplemental feed can have such high phosphorus and potassium levels that they do not need maintenance fertilization). (Undersander, 2021, 10)

Animals interact with the soil in a variety of possible ways:

1. Tread on soil.
2. Dig up soil.
3. Trample forage.
4. Deposit manure.
5. Disperse manure.

Animal treading on soil can be both harmful and beneficial to the soil. Animal treading can cause erosion, but it can also break up the soil surface allowing better water penetration.

Some grasses improve the treading tolerance of pasture. For example, sod-forming grasses are very tolerant to treading (e.g., bromegrass, reed canarygrass, and kentucky bluegrass). Adding some of these grasses may greatly increase the treading tolerance of a pasture. (Undersander, 2021, 25)

Manure is a significantly important source or recycled nutrients and its deposition can be coordinated to the benefit of the pasture. With continuous grazing, manure is less effective as fertilizer because grazing animals may concentrate manure in areas where they congregate and not where they graze. As a result, some areas receive overload and other areas receive no load. Rotational grazing improves more equal manure distribution. It is also relevant to note that grazing on lush (high water concentration) plants (and plant parts) helps distribute manure more uniformally and accelerates the breakdown and recycling of nutrients because the manure is more liquid. Extreta (e.g., manure) is essential to pastures, providing both nutrients, organic matter, water, and microorganisms. Note that animals will usually avoid eating near manure of their own species but are likely to eat right up to the manure of a different species. This avoidance is in part due to the odor of the manure to the animal that produced it. This aversion can be taken advantage of -- a species manure can be spread in an area of the pasture to keep that animal off of it. It is also relevant to note here that animal density (stocking rate) will decrease the "zone of distaste". High stocking rates will also increase manure distribution and decomposition through trampling ("hoof action"). However, animals should not be forced to eat right up to their own manure. To obtain additional nutrients, some animals will eat the manure of another species. Pigs, for example will often eat the manure of another animal. (Undersander, 2021, 25)

7.5.6 Animals grazing on insects

Insects are often abundant in flourishing ecological environments. Animals frequently graze on insects, either intentionally or unintentionally (as they graze on other foods, the attached insects are consumed inkind). Insects can be found in the pasture environment, but they can also be cultivated separately and dispersed into the pasture or they can be fed directly to the livestock animals as feedstock.

7.5.7 Animal reproduction stages

Animal reproduction phases and graphing:

1. Calving.
2. Breeding.
3. Weaning.

Food intake can be plotted against reproduction phases:

1. Early gestation.
2. Lactation.
3. Flushing and breeding.
4. Gestation.

The phases of reproductive gestation are generally,

1. Mid-gestation.
2. Late gestation.
3. Calving through breeding.
4. Breeding through weaning.
5. Mid-gestation

A survey of animal reproduction requires:

1. Pregnancy rates.
2. Body condition score.

7.5.8 Animal medical issues

Grazing animals can succumb to a number of potentially serious medical conditions. The following are some of the most relevant medical health issues to consider with pasture raised animals. Common medical issues with animals include: parasites, hoof/foot trimming, and predators. Pasture conditions and the genetics of the animal play a significant role in the presence of these conditions in any animal.

7.5.8.1 Animal diseases

Like most of the parasites, livestock diseases are passed along through mouth and nose contact, and in the feces. It is possible to limit parasite and disease transmission:

1. By separating different animal species (in a "leader-follower" system), for example, keeping cattle separate from pigs, pigs separate from the fowl, and fowl separate from the sheep.
2. Care should be taken that animals are not stressed, as stressed animals are more likely to become sick.
3. Clean water should be available to the animals at all times and watering tanks or troughs should be emptied and purged between species.
4. Pastures should not be grazed until the soil is exposed.

It is relevant to note here that wild animals can carry diseases, and if livestock come into contact with significant species of wildlife, they pick up diseases. Deer, for example can easily transmit diseases and parasites to other herbivorous animals, such as goats. Hence, it is important to not only monitor the health of the animals themselves, but the health of local wildlife and the degree of contact between the livestock and local wildlife of significance.

7.5.8.2 Animal parasites

Grazing animals can easily contract and spread parasites. Parasites are a significant and ongoing concern with certain pastured animals, most notably, sheep and goats. Regardless of the livestock species, worm eggs are deposited in the animal's manure, which then incubates the egg until it hatches. If the species that deposited the manure is allowed to graze nearby when it hatches, it will ingest the parasite. Repeated exposure of this kind will result in a build-up of parasites, which can harm the health of the animals and their productive rate.

Rotational grazing is a very effective method of parasite control since animals are moved away from their manure deposits, which incubate their species-specific parasites. Further, when they return to graze, the plant growth will be taller and since parasites tend to stay on the lower parts of the plant, the risk of parasite contraction is further reduced. Some parasites can subsist externally from their host animal in suspended animation as dehydrated cysts.

Some animals and certain breeds of sheep and goat species have greater resistance to parasites (e.g., Katahdin sheep. Sheep and goats share the same internal parasites. Pigs and chickens share the same internal parasites.

One alternative to rotational grazing for parasite control is the leader-follower method. In this model, species are grazed separately in paddocks and follow one another to clean up what the previous species chose to not graze without any fear of parasite contraction.

The best way to limit parasites in a multi-species livestock operation is to understand:

1. The types of potential parasites.
2. What the potentials of the parasite are (i.e., how they affect the animals).
3. The parasite's life cycle.

In order to limit the propagation and continuation of parasites, it is best to:

1. Not to combine livestock with similar parasites in the same or even the following paddock.
2. Always have a species break between one host species and the next susceptible species.
3. Maintain a diverse pasture forage mix, and especially a mix that includes perennial plant species that are known to be parasiticides (anti-parasitic). These can be planted along main fence lines, as well as the occasional members of the walnut and hickory species (leaves and nut husks show parasiticide effects).

Some of the most well-known anti-parasitic plants include: wormwood (Artemisia absinthium), members of the sage family in general, garlic, gentian, fennel and other strong herbs such as lespedeza.

7.5.8.3 Poisonousness plants

In many areas of the world, the existing forage mix may be harmful to one species but not another. Some plants are toxic, or mildly toxic to animals. Animals will usually avoid toxic plants, but during times of low abundance they may be driven to consume dangerous dosages of these plants. Although the occurrence of poisoning in foraging animals is probably low for a well-managed stock and pasture, animals that are most susceptible include hungry animals, travelling stock, those not accustomed to pastures that have potentially toxic plants (e.g., high oxalate, etc.).

Problem plants that are poisonous to many species, such as certain thistles and poison hemlock, pose little danger to goats. Additionally, some plants are only dangerous at certain times of their life-cycle. For example, buffel grass (a valued pasture species for livestock) can have very high concentrations of soluble oxalates, particularly when it is young and actively growing.

Samples of pasture plants should be collected and tested to determine toxicity for future grazing species.

7.5.8.4 Nitrate poisoning from plants

Nitrate poisoning acts quickly and is hard to detect before being fatal. When animals consume these high-nitrogen foods at too high a species excess, their body fails and they die. Certain plants have a tendency to concentrate more nitrates than others (e.g., lambs quarters, pig weed, annual grains, etc.). Nitrate accumulation can come after excessive environmental disturbance, including drought, too mush shade, and herbicide application. The application of any manure or fertilizer will also increase the quantity of nitrates in the soil. (Undersander, 2021, 38)

7.5.8.5 Oxalate poisoning from plants

High oxalate feed is dangerous to many animals. Oxalate levels in plants can vary depending on the growth stage of a plant. Non-ruminants appear to be more sensitive to oxalate than ruminants because in the latter, rumen bacteria help to degrade oxalate. If ruminants are slowly exposed to a diet high in oxalate, the population of oxalate-degrading bacteria in the rumen increases sufficiently to prevent oxalate poisoning. (Rahman, 2012)

7.5.8.6 Bloat from plants

A medical condition where foam producing compounds of immature plants cause continuous foam production in the rumen (of susceptible animals). This foam prevents them from belching rumen gas. This disease can quickly lead to an animals death. We already have the logistics of complicated social economic relations in a manner that allocates goods and services efficiently using non-market based solutions. (Undersander, 2021, 37-38)

Bloat can be significantly avoided and prevented with several principles/practices (Undersander, 2021, 38):

1. Do not graze hungry animals on pure legume pastures. Feed the animals with hay before releasing them on a pasture with the potential of causing bloat. Leave feed on a pasture continuously so the animals do not gorge themselves.
2. Move the animals frequently.
3. Feed poloxalene to the animals as an anti-foaming agent.
4. Avoid grazing legumes and brassicas rain or dew on them.
5. Avoid grazing grass and legume pastures that are in an immature stage.
6. Plant non-foaming plants (e.g., the legume birdsfoot trefoil).

7.5.8.7 Anti-herbivory (plant bio-chemical defenses)

A.k.a., Antiherbivory, anti-consumption bio-chemical defense.

Classification of anti-herbivory compounds includes:

1. Nitrogen compounds:
   A. Alkaloids.
   B. Amines.
   C. Non protein amino acids.
   D. Cyanogenic glycosides and Glucosinolates.
2. Terpenes:
   A. Monoterpenes.
   B. Cartenoids.
3. Phenols:
   A. Simple phenols.
   B. Polyphenols.
4. Acids:
   A. Oxalic acid (oxalates).
   B. Etc.

7.6 Pasture area control [plan]

It is essential to remember that pastures conditions may vary with season, and the control of pasture areas may need to account for this dynamic environment with flexibility of decisioning.

Computational factors relevant to pasture coordination control include:

1. **Time** - the duration animals remain in a given grazing area.
2. **Number** - the number of animals on the grazing area (stocking density).
3. **Area** - the land available for grazing.

Technical pasture control practices include, but are not limited to:

1. Fencing.
2. Water development.
3. Animal trails and walkways.
4. Herding.
5. Behavior modification.
6. Salt and supplement placement.

The non-fencing approach (which still includes some fencing) involves created a permanent herd with multiple species in the same paddock together (e.g., cows, goats, and donkeys. A mixed species herd may be significantly less prone to seek a way out through the fencing. The animals are rotated into each paddock together, instead of having them follow a leader-follower procedure.

Pasture quality acceleration practices include, but are not limited to:

1. Brush management (e.g., controlled, cutting, clearing).
2. Prescribed/controlled burning.

3. Range or pasture planting.
4. Nutrient management (chemical management).
5. Irrigation water management.

7.6.9 Animal transportation

There are different possible types of animal transportation in a cultivation system, these include:

1. Mobile animal harvesting machines.
   A. Milking mobiles - a trailer used to milk lactating animals.
   B. Chicken hut trailer - a trailer used to transport animals like hens from one paddock to the next.
2. Animal trailers.
   A. Most often used to transport animals for harvest.

It is important to train the animals to load into a trailer from a young age. Somewhere in the grazing paddock system park a livestock trailer. When animals are not trained to load into a trailer from a young age then loading them can be challenging and unnecessarily stress the animals. When the cattle are in that paddock lead the animals into the trailer where they find a tasty treat of a well-balanced feed. Simultaneous with the livestock discovering the tasty treat the herder should give out a species-specific whistle or call. As this happens periodically through the grazing season, the animals become familiar with the trailer. They see it frequently, they graze near and around it frequently, and they get a morning treat inside of it along with scratches and pats from the human. The animals become comfortable with seeing the trailer arrive and seeing it drive away. Eventually the trailer becomes associated with a positive experience. Once on pasture for sufficient time, animals may needed to be transported for harvest.

It is relevant to note here that mobile coops are crowded, hot, stink, are hard to clean, and hard to move. If used, mobile coops should be on a tractor bed, or on some other easily moved platform. Moving chickens is best done through open-bottomed, portable chicken pens or trailer-mounted, mobile chicken coops. Buying enough square-mesh portable electric fence to set up permanent paddocks for all of the chickens that you can raise is quite expensive. And moving mesh-fence paddocks every day is a lot extraneous and unnecessary work.

7.6.10 Predation

Under specific bio-geographic conditions grazing animals may have predators in the local environment. Livestock protection from predators includes, but may not be limited to:

1. Guardian dogs, such as Great Pyrenees or Anatolian Shepherds. These animals will defend the herd when attacked.
2. Goats and sheep often played the role of an early warning system and retreated to the herd when a predator is identified As a result, while the sheep and goats sometimes venture away from the herd, but at the sign of any trouble, they retreat to the herd with the larger cows.
3. Donkeys are very effective guardian animals, instead of dogs. They are part of the herd, just like all the others, and our two donkeys often stand quietly facing opposite directions, ready to stomp any invader. These animals will defend the herd when attacked. Use donkeys to kill predators.
4. Bulls can be a permanent part of the herd (humans must be careful around bulls as they can be very dangerous). These animals will defend the herd when attacked.
5. Fencing perimeters.

7.6.11 Riparian area grazing control

A riparian zone or riparian area is the interface between land and a river or stream. Riparian area grazing coordination involves (Undersander, 2021):

1. Attract livestock away from riparian areas:
   A. Offsite water developments.
   B. Manipulation of upland vegetation.
   C. Supplementation.
2. Excluding use or promoting avoidance of riparian areas:
   A. Fences, barriers, stream access points, low-stress herding.
3. Herd coordination and animal husbandry:
   A. Culling practices - "riparian areas".
   B. Breeds.

7.7 Grazing rotation control [plan]

A.k.a., Livestock movement control.

The rotation of grazing animals can be done in an automated, semi-automated, or manual form. Batlatch automated computer operated gate openers allow for the automated opening of gates between pastures. No humans have to be there when the gate opens and the livestock move naturally to the next paddock. Tumble wheels for movable fencing.

7.8 Grazing plan development

A grazing plan requires the following elements:

1. Describe present coordination; identify opportunities, issues, problems.
2. List what resources are available to work with (land, allotments, resources, facilities, animals, soils, plants, water, equipment).

3. Determine objectives.
4. Determine animal needs and timing.
5. Determine plant needs and timing.
6. Determine coordination/management tools and techniques.
7. Design the plan, grazing strategy, contingency plan for disasters.
8. Determine monitoring design.

A grazing plan requires at least two assessments and one calculation:

1. Conduct a pasture resource assessment:
   A. Identify pasture size.
   B. Identify pasture composition.
   C. Identify pasture state/status.
2. Conduct a species resource assessment:
   A. Identify the animal and forage species.
   B. Identify the animal availability (do you have the animal).
   C. Match animal needs with forage production.
3. Calculate an optimal paddock size and rotation schedule (be flexible).
   A. Identify optimal foraging time and schedule, including optimal grazing and rest periods for a pasture.

A grazing plan requires rotational coordination:

1. Determine the number of animal units that will be in the grazing system.
2. Estimate how many hectares will be needed throughout the grazing season.
3. Estimate how large each paddock should be.
4. Estimate the number of paddocks needed.

The plan must account for all relevant resources, including:

1. **Land resources.**
   A. Land base (soils, plants, minerals) for a year-round ranch plan.
   B. Private lands – irrigated pastures.
   C. Public lands – rangelands.
   D. Soil resources.
   E. Water resources.
   F. Mineral resources.
2. **Technology resources.**
   A. Fences.
   B. Facilities.
   C. Equipment.
   D. Etc.
3. **Animal resources.**
   A. Cultivated animals (livestock and animal companions).
   B. Wild animals (wildlife).
   C. Feral animals (i.e., animals that belong to a domesticated species like cats and horses, but live wild).
4. **Plant and other species resources.**
   A. Cultivated plants (food and medicine, aesthetics)
   B. Wild plants (wildlife).
   C. Feral plants (i.e., plants that belong to a domesticated species like, but live wild).
5. **Human contribution.**

Guidelines for a grazing plan include:

1. Provide as much growing season recovery time as possible (i.e., reduce duration of grazing for each unit).
2. Consider the rate of plant growth (soil moisture and temperature) in planning duration.
3. Increase the number of pastures (use areas) and stock waters to increase flexibility.
4. Consider combining herds to make more pastures available.
5. Try not to graze the same unit at the same time of the year every year. *Why?*
6. Adjust the intensity to match the season and duration of use.
7. Make the whole plan fit together.
8. Develop a contingency plan.

7.8.1 Identify the animal species

It is essential to identify the animal species to be grazed on the pasture (and therein, paddocks). There are a number of factors that go into the selection of specific species of animal:

1. Geographic and climactic location
2. Soil type
3. Plant type
4. Predator type
5. Disease types in area and common to a species
6. Desired noise level

7.8.1.1 Select animals, grazing species and breeds

Choosing breeds of animal for pasture grazing involves the following significant decision factors:

1. Choose breeds that require little labor. For example, wool sheep require shearing, but hair sheep (such as Katahdin) do not. Choose breeds that fit the environment.
2. Choose parasite-resistant breeds.
3. If you supplement with minerals, take care to choose appropriate minerals and quantities. For example, as sheep are more sensitive to copper than cows.

4. Identify local recommendations for animal species and land access. For example, for every one hectare there could be one cow, one calf, two goats, one sheep, ten chickens in movable hen-houses (no roosters), two turkeys. Maybe for two hectars, there could be three cows, three calves, three sheep, six goats, 30 chickens, six turkeys.

7.8.1.2 Identify desired noise level

The noise level in a rotationally pastured environment is based on the following factors:

1. There are guardian dogs, and will they make noise.
2. Bulls separated from cows will call the cows.
3. Roosters have loud early morning calls.
4. Equipment will make noise also.
5. There are loud breeds of goats and other livestock, and there are quiet breeds of goats and other livestock.

7.9 Carrying capacity of the land (ecosystem)

A.k.a., Production capacity, carrying capacity calculations, production capacity calculations, animal space requirements.

There is land where no food producing animal can live, and there is land that can support many animals (e.g., cattle, or a mix) per hectare. Certainly the productive carrying capacity of the land can be increased/optimized given appropriate conditions, such that it supports the most (or, more) animals (e.g., just cattle or a mix of species) per hectare. The number of a species of animal per area (e.g., hectare) is called the "stocking rate". For cattle and some other species of livestock, stocking rates are based upon how many head can be run on an acre of land without over-grazing it.

QUESTION: *How many animals can be foraged per hectare; how long can they forage in each paddock before needing to be moved to another?*

The carrying capacity of land depends on numerous factors:

1. Are the animals (e.g., cattle) going to be free ranging on pasture grown grass?
2. What are the land's elemental factors: soil type, terrain type, vegetation type, and water availability over the land area?
3. What type of plant (e.g., grass for cattle) is grown (wild/seeded)?
4. What is the nutritional value of that grass?
5. How much water/rain/irrigation does that grass need?
6. Are the animals (cattle, sheep, etc.) on irrigated pasture?
7. Is there a dry season, for how long does it last, and how much land needs to be dedicated to growing feed for stock reserve for when the land is dry and the available forage is low?
8. Is the grass available year around?
9. Is the grass fertilised/rested? (Organic with crop rotation or manufactured)?
10. Age of animal (cattle) being raised (i.e., calves, yearling, bullocks)?
11. Is any of the land eroded and ungrazable from the livestock during their time there?
12. How much of the land is rocks?
13. How much of the land is cultivated for feed?
14. Are there parasites in the environment that could harm the health of the animals?
15. Is supplement feed given?

It is possible to calculate animal type, number and weight per hectare given a set of variables:

1. Animal type (cattle type).
2. Pasture area (exclude non-forage cultivation area percentage).
3. Forage production of field.
4. Annual precipitation.
5. Pasture condition.
6. This is put will be used to determine:
7. Estimated forage yield in kg/ha.
8. Utilization [of forage] rate in % of total available utilized).
9. Total forage available.

Several key questions to ask when determining capcity are:

1. How much plant matter and of what quality and species do the animals need?
2. How much insect matter and of what quality and species do the animal need?
3. How much water and of what quality do the animals need?

Flat pastureland with access to fresh water in numerous places will allow animals (sheep in particular) to graze more efficiently than they would on rough, hilly and/or rocky terrain with access to water in only one location.

7.9.1 Generalized animal area requirements

The following is a generalized estimate for the area nutritional requirements of different animals species:

1. **Cattle** (stocking rates of cattle as the animal unit)**:**
   A. A general estimate for cattle is that 20-30 head of cattle can occupy 9-15 hectares of non-degraded (reasonable quality) pasture land.

2. **Goats (**stocking rates of goats as the animal unit):
    A. Goat stocking rates must be based upon controlling internal parasites and avoiding over-crowding. Goats are very susceptible to internal parasites, particularly the blood-sucking stomach worm Haemonchus contortus (barberpole worm) that causes anemia and death. Goats, similar to deer, need lots of land to roam over. By moving continually and eating from higher elevations downward, goats avoid worms that are on plant materials that are closest to the ground.
    B. With reasonable pasture it is possible to have between 6-8 goats per 0.4 hectares. This number will be raised or lowered depending on the size of the goats and the land's available resources. Depending upon the area, goats in particular can clear about 0.8 hectares a day.
3. **Sheep** (stocking rates of sheep as the animal unit):
    A. Some sheep breeds are smaller/larger than others, and will require more/less space.
    B. A pasture in condition can typically support 10 ewes and 15 lambs per 0.4 hectares of pasture.
    C. 12 hectares properly irrigated and fertilized pasture land should be sufficient to supply a flock of 100 ewes and 150 lambs each year. (Outhouse, 2007)
    D. A pasture of just 0.4 hectares of land can usually produce enough forage to sustain two sheep year-round. However, you can keep up to 8-10 sheep on one acre if you regularly rotate your fields and provide extra roughage, like hay.
    E. With smaller sheep breeds, like babydoll sheep, 0.4 hectares of land can sustain as many as five sheep.
    F. Sheep usually eat 2.5 – 3% of their body weight each day; depending on how much you sheep weighs, that means they can be eating 2 – 7 lbs (1 – 3.2 kg) per day. If you have 10 sheep, your flock may require up to 70 lbs (31.8 kg) of food per day.
4. **Mixed animal species (mixed species animal units):**
    A. Good condition pasture of 1.61 hectares with 0.2 hectare paddocks (for a total of 8 paddocks) can support 5 cattle, 17 sheep, and 250 chickens.

7.9.2 Calculate for optimal paddock size

The following information can be factored to calculate for optimal paddock size:

1. Experiment and test.
2. How many animal units are being grazed?
    - Animal unit (AU) - 500 kilograms
3. What is the grazing capacity of the area?
    - Carrying capacity - the number of days it is possible to graze 1 AU on a hectare before moving the animal to another paddock and letting the area rest for the remainder of the year.
4. Calculate the square meters required per paddock for one day:

    Carrying capacity / Animal units = sqr m

7.9.3 Calculate for optimal paddock number

To determine the optimal number of paddocks for a rotational grazing system, it is necessary to estimate (identify):

1. The length of the longest rest period (often, occurring during the slowest period of forage growth).
2. The length of the grazing period.
3. The number of species and animal groups that will be grazing sequentially.

Paddock numbers can be calculated from the following formula:

Number of paddocks = (rest period / grazing period) + number of animal groups

- For example, a pasture with 15 day rest periods and 5 day grazing periods that is grazed by 1 animal results in determination of 3 paddocks as appropriate. ((15 / 5) + 1) = 3 paddocks.

7.9.4 Calculate for land capacity

The carrying capacity of a set area of land is the number of animals that can be sustainably grazed on the available land over a season or year (an elongated period of time). Carrying capacity is measured over a long period of time, either a season or a year. The critical piece of that definition is sustainably grazed. Sustainably grazed refers to a feed-stocking rate (not animal-stocking density) that allows animals access to their daily feed requirements while maintaining the resource base of the land. If more animals are grazed than the land can support over a season, then the resource base will begin to deteriorate in the form of decreased plant species, erosion, increased weed pressures and decreased productivity. If the land has stopped producing sufficient feed to support the life requirements of the number of animals, then remediation action must be, which may include a reduction in the population of the species.

Calculating for land capacity requires:

1. Calculating the current carrying capacity of the

pasture(s).
   A. Identify amount of land available.
   B. Identify amount of feed available on land.
   C. Identify amount of feed available in stock (feedstock).
   D. Calculate optimal animal to feed solution given available conditions.
2. Calculate the future expected carrying capacity of the pastures.
   A. Calculate optimal animal to feed solution given future available conditions.

There are four basic data-points that go into the carrying capacity calculation:

1. **Forage production (in kilograms/hectare)** - Forage production is expressed in kilograms/hectare. Estimates should be specific to a forage species and the specific climactic- and bio-region. The result should be expressed in: Dry matter (with units, kilograms/hectare). Animal nutrition requirements, expressed as daily dry matter (DM), which are species associated numbers (note: this data is easily found online). Alternatively, it is possible to calculate the actual production value by clipping, drying and weighing your forage in the context of soil nutrient content and plant nutrient type [for a/the species].
   A. Macro-nutrient dry matter available?
   B. Micro-nutrients available?
   C. Species and number of organisms available?
   D. Species life stage requirements?
2. **Utilization rate (in percent usage, e.g., .50; consumption over paddock rotation in a season or duration of time) -** At what rate (usage over time) is feedstock being consumed?
3. **Regeneration rate (in percent regeneration, e.g., .50; regeneration over paddock rotation in a season or duration of time)** - At what rate (regeneration over time) is the feedstock being regenerated?
4. **Animal nutrition requirements (dry matter in kilograms per day; matrix of specific amounts)** - What are the animals nutritional requirements in dry matter?
5. **Length of growing season, grazing season (duration of time, often in days)** - What is the time length of the growing season; what is the time length of the grazing season?

The equation for the carrying capacity of land by selected single species is:

1. How many of animal *A (,B,C,...)* can be put on *X* hectares of pasture?
   - What is the carrying capacity of the land per hectare?

   Hectares Carrying capacity = (Forage Production) x (Utilization Rate) x (Available Hectares Carrying Capacity) ÷ (Daily Intake) x (Growing Season)

   For example: Carrying capacity = (12 kg per hectare) x (.5 utilization) x (5 kg of DM per day) ÷ (4 kg of DM per day) x (12 months) = 90 organisms per hectare [can be carried on the pasture land]

2. How many hectares are needed to support *N* number of animals?
   - How many hectares are required for the desired size of the population?

   Hectares Required = Number Of Animal x Daily Intake x Growing Season ÷ Forage Production x Utilization Rate

   For example: (90 organisms per hectare) x (4 kg of DM per day per organism) x (365 days) ÷ (12 kg per hectare) x (.5 utilization) = 180 hectares of land are required for the population size

The same information for a one-species calculation must be added to for a multi-species population. Herein, reference to a specific animal (e.g., cow or sheep) is removed and replaced with the unit label "animal unit" or AU.

To translate our results into various combinations of animal species, an equivalence chart (equivalency chart) is required. There are many different versions of this chart, but most differences are subtle and unimportant.

- The NRCS National Range (2003) and Pasture Handbook contains a reputable equivalence chart.

Calculate the numbers for specific individual species in 1 and 2 above, and then, divide the results (now AUs) by the equivalent number from the chart:

Multi-species carrying capacity = Per hectares carrying capacity ÷ charted equivalence

Carrying Capacity = 90 (cows) ÷ 0.02 = 2,330 (rabbits)

7.9.5 Required determinations for a multi-species rotational grazing system

A multi-species rotational grazing system involves the following determinations (Williams, 1996):

1. Determine the number of animal units that will be in the grazing system.
2. Determine the forage requirements of the

population of animals using animal units (AU).
3. An animal unit (AU) is equivalent to the daily forage intake of a 453kg cow (~11kg/day).
4. Determine total AU of herd adding up all the AU to get a total for the whole population.
5. Estimate how many hectares will be needed throughout the grazing season. Estimating the number of hectares required to pasture a population depends on both
   A. The feed requirements of the animals.
   B. The available forage produced.
   C. Pasture growth is dependent upon:
      1. Plant species.
      2. Soil characteristics.
      3. Topography.
      4. Fertilization.
      5. Temperature.
      6. Soil moisture.

   Note: Because of the variability in pasture growth, we can only estimate the number of acres required for grazing animals. Table 2 provides some estimated values of the acres required for grazing animals on various types of pasture.

6. Estimate how much pasture a population will need, first calculate the total AU of the herd (Step 1). Using a species forage table, estimate how many acres each AU will need during each month of the grazing season.
7. Estimate how large each paddock should be. Use a table that includes paddock sizes based on grazing period and available pasture. Use a table of suggested paddock sizes (hectares per AU) for rotational grazing. Paddock size depends on:
   A. The animal units (AU) in *kg* of the herd.
   B. The amount of available pasture at the beginning of grazing.
   C. The desired grazing period.

   Note: Available pasture is pasture present in a paddock at the start of grazing minus the amount present when the animals are removed from the paddock. Depending on plant density,

8. Estimate the number of paddocks needed. The number of paddocks needed for a rotational grazing system will depend on the number of days the animals graze in a paddock and the maximum rest period needed. Rest periods should be based on the growth rate (regeneration rate) of the pasture, which will vary with the season and weather conditions.
   A. Identify the maximum days rest and divide by number of days grazing + 1 = paddock number
   B. Example: The herd will graze each paddock for 3 days, and the maximum rest period between grazings will be 35 days.
      • (35 days rest divided by 3 days grazing) + 1 = 13 paddocks

   Note: Species and class of grazing animal may determine the grazing period.

Additionally, it is much preferred is so much better to have too much grass and not enough animals at the end of this calculation than the other way around.

7.9.5.1 Animal forage stocking rate

A.k.a., Feed restocking rate.

In concern to the quantity of forage, the resource allocation rate (forage stocking rate) is the number of specific kinds and classes of forage or utilizing a unit of land for a specific period of time. (NRCS-NRPH 1997) The selection of the optimal stocking rate is the most important of all grazing coordination decisions. (Holecheck et al, 1999)

The method of determining initial stocking rates is:

1. Determine land area in squared units.
2. Determine forage area in squared units.
3. Determine individual forage demand (e.g., 3% of body weight, BW, or 13 kgs/day air-dry).
4. Select harvest coefficient.
5. Adjust for distance from water.
6. Adjust for slope.
7. Compute correct stocking rate.
8. Cross check actual and expected use.

7.9.6 Deciding a grazing and resting schedule

Determine a schedule of when to move the animals from one pasture to another. The number of paddocks grazed and the length of the grazing and rest period can (and often, should) vary as pasture growth rates change with the weather and climate; this is a flexible pasture schedule.

7.9.7 Optimal grazing time for plants

The goal of a grazing system should be to maximize both forage yield and quality. The best time to graze most grass, for example, is immediately before flowering and seeding. Species develop differently however and the best time to graze one grass species may not be the best for another. For grass, there is a two variable spectral graph with:

1. An *x-axis* as yield (low yield when young to high yield when old).
2. A *y-axis* for feed quality that goes from (high quality when young to low quality when old).

This graph plots the grass (or other feed) in concern to yield from the plant and quality of the plant for animal feed. When including animal requirements, a best time to graze can be determined from the graph plot. The best time to graze is where yield crosses quality (of food for animal).

Summarily, phases of grazing plant maturity includes:

1. Phase 1 (non-optimal grazing)
2. Phase 2 (optimal grazing)
3. Phase 3 (non-optimal grazing)

In general, as plants mature, growth slows since most energy is diverted to flower and seed production. While yield is highest at the start, quality is very low. Quality is high when plants are small and vegetative. Quality declines as plants mature. This occurs because as plants get larger and stemmier, a greater percentage of nutrients and dry matter is bound up in indigestible forms (such as lignin). Greater amounts of indigestible fiber result in lower quality forage with decreased amounts of total digestible nutrients (TDN). (Undersander, 2021, 6)

7.9.8 Pasture grass grazing capacity

A.k.a., Pasture productivity.

There are two general methods of estimating pasture capacity (pasture productivity). (Undersander, 2021, 19)

The first method is the direct estimate method (note: example weights are given):

1. Clip and collect - collect the forage in 1 square meter of pasture. Clip at the intended grazing height (note, this will vary with species).
2. Weigh and record the forage. Take all measurements in kilograms (e.g., 2.07 kgs/sq meter).
3. Dry a sample.
   A. Record the weight of an empty paper plate (e.g., 1kg).
   B. Take a half pound sample, approximately, of the forage. Place it on the plate and weigh it (e.g., 4 kg).
   C. Place the same in a microwave oven along with a cup of water. Turn on the microwave (on high) for 3 minutes. Weigh the sample. Warning: leave the water in the microwave throughout the drying process. The water reduces the chance of damaging the microwave or starting a fire.
   D. Microwave the same for another minute, then reweigh the sample. Repeat this step until the weight remains the same.
   E. Record the final sample weight (e.g., 2 oz).
4. Calculate the percent forage dry matter (DM):

   % forage dry matter = (final weight of sample - weight of plate) / (original weight of sample - weight of plate)

   Example: (2oz - 1oz) / (4oz - 1oz) = 0.333 (33% forage dry matter)
5. Determine pasture probable yield:

   Pasture yield (kgs/hectare) = [(total weight of forage (step 2)) * (% forage DM (Step 4)) * (10000 sq m/ hectare)] / 1 square meter

   Example: (2.07 kgs/sq m) * .33 * 10000 sq m/ hectare) / 1 square meter = 6,831 kg/hectare

The second method is the pasture plate method:

1. Make a the plate tool.
   A. An 45.72cm square sheet of acrylic (0.55-cm thick), a meter stick, and a 5.08cm bolt.
   B. Drill a 3.81cm hole in the center of the plate. The meter long measuring stick goes through the hold and a bolt is attached to the bottom of the meter stick.
2. Instrument usage.
   A. Place the meter stick on the ground.
   B. Hold the plate on the meter stick about 1 foot above the standing forage and let it drop.
   C. Record the plate's height (in centimeters) off the ground.
   D. Take measurements in 5 to 10 locations in the pasture and use the average height.
   E. Calculate dry matter yield (kgs/hectare) by multiplying the height by 390.
   F. For accurate results the plants must be dry when taking using the instrument.

   Pasture yield (kgs/hectare) = 390 * height (cm)

   Example: 390 * 6 cm = 2340 kgs/hectare

7.9.9 Contingency planning

Contingency plans account for potential environmental and coordination problems, including but not limited to:

1. Extreme climactic events:
   A. Drought.
   B. Excessive rain and/or flooding.
   C. Wildfires.
2. Predators:
   A. Animal predators.
3. Insects:
   A. Non-biting insects.
   B. Biting insects.

Contingency plan techniques include, but not limited to:

1. Put additional hay or other food on pasture.
2. Reduce herd size (cull open cows, replacement heifers, broken mouth, older animals).
3. Early weaning.
4. Alternative feeds (corn stalks, alfalfa stubble, human food scraps).
5. Acquire additional grazing land.

7.9.9.1 Backup and supplemental forage (stockpiling forage)

A.k.a., Stockpiling food, silage.

The length of the grazing season need not be restricted to the length of the growing season. Stockpiling means allowing an accumulation of forage for later use. The technique is to defer grazing on a portion of the pasture beginning in fall. This forage is allowed to accumulate and is grazed throughout the fall and winter after pasture growth has stopped. Certain grasses and plants should be avoided in they produce relatively little growth in the fall. If there is little pasture area to set aside stockpiling forage for fall and winter grazing, then it is probably not a good option.

7.9.10 Grazing system monitoring

Monitoring of a grazing system must include:

1. It is essential to understanding the effects of coordination decisions and actions on the health and sustainability of land.
2. Document successes and failures.
3. Document annual grazing use.
4. Document climatic conditions.
5. Document long-term trend in vegetation – photo points, transects, utilization cages.

Observations of the animals, pasture, coordination plans and ideas should be recorded as part of a continuous monitoring process:

1. **Animal observations** - try to match animal needs with forage production.
   A. Record animal health problems that might be grazing related.
   B. Keep track of forage stocking rates. Are the rates high enough to prevent spot grazing.
   C. Are the animals camping in specific areas?
   D. Are the animals getting enough forage from the pasture? Why or why not?
   E. Is there significant trampling loss?
   F. Is production at desired levels? Do animals need supplement or does the pasture need renovating?
2. **Pasture observations** - try to match pasture conditions to animal needs.
   A. Keep track of rest and grazing periods. How is the pasture responding to these periods? Does the pasture recover slowly?
   B. Keep track of species movement schedule.
   C. Keep track of the species of the forage.
   D. Keep track of the growth stage of the forage. How long does it take to reach, from seed and/or regrowth, to reach optimal stage for grazing?
   E. How much stubble is being left by the animals?
   F. Is it possible to extend the growing season?
   G. If forage is being stockpiled, how much forage do you need?

7.9.11 Adaptive pasture coordination

Adaptive pasture coordination includes four project phases that represent a whole cycle:

1. Plan (assume that the system can continually be improved).
   A. Evaluate the present land (condition, situation, status).
   B. Identify a 3 to 5 year plan for improvement of the land.
2. Implement.
3. Monitor.
4. Review and revise.

Pastures may need renovating, or new plot of land may need a pasture created within it. Some important questions to ask in consider to pasture renovation (Read: cultivated terrain modification) include, but are not limited to:

1. What is the current condition of the land?
2. What change in condition should the new state of the land have?
3. What is the species composition of the land?
4. What change in species composition needs to take place (should the new state have)?
5. How long will it take to sufficiently modify the state of the land?
6. Is tillage and an option? Is it possible to tillage good soil, compost, and manure into dry and dead soil, and clay?
7. Is herbicide an option?

7.9.12 Grazing system matrix

A grazing system matrix is a tool for grazing coordination that defines systematically recurring periods of grazing and deferment for two or more pastures (or, grazing control) units. (NRCS-NRPH, 1997)

A grazing system matrix must include one or more of three basic elements:

1. Deferment (non-use for less than a year).
2. Rest (non-use for a year or more).
3. Rotation (livestock movement on a schedule basis).

Grazing system land usage:

1. Range land (rangeland):
    1. Continuous or season-long.
    2. Deferred rotation.
    3. Rest rotation.
    4. Short duration.
2. Irrigated pasture:
    1. Continuous or season-long.
    2. Rotational or coordinated intensive grazing.

A grazing system matrix must account for the selection of foraging species based on cultivation viability:

1. Climate type and viability - different climates will provide different levels of productivity.
2. Soil type and viability - different soil types will provide different levels of productivity.
3. Moisture level and viability - different moisture levels will provide different levels of productivity.
4. Nutrient level and viability - different nutrient levels will provide different levels of productivity.
5. Grazing intensity and viability - different grazing coordination methods will provide different levels of productivity.
6. Desired length of grazing period - different grazing lengths will provide different levels of productivity.

7.10 Animal body processing for human food

An animal processing facility ought to honor the death of the animal like it was honored during its life cultivation. Humans ought to give their cultivated animals a fulfilling life and thank them for their death by honoring the procedures by which they are killed for their bodies to provide nutrition for human need.

7.11 Animal derived products

There are many products that can be derived and made from the carcases of animals, including but not limited to (and because animals are all organic, the whole body both food and fertilizer):

1. Brain:
    A. Food.
    B. Medicine.
    C. Creams.
2. Blood:
    A. Food.
    B. Adhesives.
    C. Baking mixes.
    D. Dyes & inks.
    E. Medicines.
    F. Minerals.
3. Bones and marrow:
    A. Food.
    B. Charcoal.
    C. Fertilizer.
4. Hair:
    A. Air filters.
    B. Brushes.
    C. Felt.
    D. Hair.
    E. Insulation.
    F. Plaster.
    G. Textiles.
5. Skin:
    A. Leather.
    B. Gelatin.
    C. Adhesives.
    D. Flavorings.
    E. Medicines.
6. Fat:
    A. Food.
    B. Vitamins.
    C. Oil and lubricants.
    D. Antifreeze.
    E. Biodiesel.
    F. Candles.
    G. Cement.
    H. Deodorant.
    I. Cosmetics.
    J. Crayons.
    K. Creams and lotions.
    L. Linoleum.
    M. Paint.
7. Feet, hooves and horns:
    A. Food.
    B. Adhesives.
    C. Conditioner.
    D. Lamination.
    E. Photo film.
    F. Plastics.
    G. Plywood.
    H. Wallpaper.
8. Internal organs:
    A. Food.
    B. Peptides.
    C. Vitamins.
    D. Minerals.
    E. Medicines.
9. Milk:
    A. Food.
    B. Medicines.
    C. Adhesives.

   D. Cosmetics.
   E. Plastics.
10. Manure:
   A. Fertilizer.
   B. Nitrogen.
   C. Phosphorus.

8 Aquatic cultivation specifics

A.k.a., Restorative aquaculture.

Animals may be cultivated along with plants in an aquatic environment. Restorative aquaculture, also known as aquatic cultivation, refers to the practice of raising aquatic plants and animals in a manner that not only produces food and commercial products but also contributes positively to the environmental health of aquatic ecosystems. This approach to aquaculture aims to restore, conserve, or enhance the natural productivity and biodiversity of marine or freshwater habitats.

9 Fungal cultivation specifics

A.k.a., Mycological cultivation.

A simple way to dispose of surplus woody material is to convert the inedible wood into the edible, or otherwise useful, fungus. Mushroom logs or wood chip beds can be inoculated with specific fungal species. These fungal decomposing logs can be placed in different locations on-pasture, or nearby structures for human selection.

Branches and logs can be inoculated with fungal spores. Inoculated logs can be placed anywhere in or around a pasture to be inoculated with fungal spore spawn. Often, in agroforestry environments, logs are placed on the ground between the trees in a row or between rows of trees.

It is important to note here that not all fungus is good fungus, some fungus is harmful to plants, and some fungus is harmful to animals.

The following can be inoculated with symbiotic fungal spores:

1. Compost can be inoculated.
2. The soil can be inoculated.
3. The feed and water of livestock can be inoculated.

NOTE: *Edible fungus that grows on cattle dung can be started by mixing the spores in the drinking water of the cattle. The cattle will consume the spores and the spores will produce the fungus in their dung.*

9.1 Fungi and bacteria

To stimulate fungal growth in the soil, it is important to previously (or, simultaneously) stimulate commensurate bacteria. The appropriate bacterial species will provide a substrate and environment in which the fungi can thrive.

10 Insect cultivation specifics

Feed food waste to insects. The flavor of an insect to another consuming animal can be changed by changing the feed fed to the insect.

10.1 Honeybee pasture-based cultivation

A.k.a., Pasture-based honeybees.

It is relevant to note here that in a diverse ecological system the honeybee is not needed for pollination services; there are many other insect pollination services generally available. Bees can provide a number of ecological services for the ecology and humanity:

1. Bees provide an ecological crop pollination service. It is estimated that approximately 87% of flowering plants rely on pollination.
2. Bees provide a source of simple carbohydrates in a matrix with other plant compounds.
3. Bees provide a source of wax source.
4. Bees can also provide to some extent other chemicals, such as pollen, royal jelly, propolis, and venom.

Honeybees (from Europe) are only one type of pollinating insect, of the genus Apis and in the Apidae family. Prior to the introduction of the European honeybee, insect pollination of most flowering plants was taken care of by number of species of flies, beetles, wasps, butterflies and moth. Note here that some plants require insects for pollination, others are pollinated by wind (e.g., oaks, chestnuts, beech, hazelnut, butternuts, walnuts, pecans, wild rice, corn, etc.). However, the most effective pollinating insects are bees. European-type honeybees derive their sustenance from flowering plants. (Shepard, 2013)

Pollen, which is analogous to the male reproductive cells of a plant, is high in the protein required by bees to build their bodies. Nectar is a liquid secreted by the analogous female portions of a flower and it has no apparent reason for existing except as a lure to attract pollinating insects. Nectar is high in sugars — fructose, glucose and the like — which are an extremely high-energy drink. All bees eat pollen and drink nectar for their sustenance. When bees crawl around on the anthers of a flower in order to eat pollen, or even when they bypass the pollen en route to the nectar itself, some pollen sticks to tiny bristles that cover the bee's body. As the bee laps up the sweet nectar some of the pollen covering its body may make contact with the stigma (analogous to the vagina in female mammals) of the flower, where it will eventually travel through the style to make contact with an ovum and create a new seed. After a drink of nectar the bee travels up out of the flower and eventually combs itself to remove the stray pollen grains from its hair. Much of the pollen is stored in specialized regions on the legs, inaccurately called pollen sacs, where it is taken back to the nest to later serve as a food source for larval bees.

Many species of plants cannot use their own pollen and have to receive pollen from other individuals of their same plant species in order to produce viable seed. Bees pollinate flowering plants in the process of feeding themselves. The functional relationships is that the flowering plant feeds the bees, the bees pollinate the flowers to make more flowers, which feed the bees.

Bees produce honey. Like cane sugar and maple syrup, honey is a high-sugar, simple-carbohydrate sweetener. One pound of honey is likely to have over 1,382.4 calories in simple carbohydrate form. One hive of honeybees located in the northern United States can easily produce over 50 lbs. of surplus honey per year. If only two hive were kept on one hectare, those two hives would add a possible additional 138,204 calories to the system. (Shepard, 2013, p112)

There are many ways to cultivate bees over time by how their beehives are dealt with. Historically, the stronger hives would be kept and the weaker hives harvested. Historically, the beehives were harvested by drowning them in water or smashing them open. In the case of culling weaker hives, the strongest hives had produced more honey and therefore would have more reserves to feed them through the winter when there are no flowers in the fields and forest. The strongest hives would obviously have stronger queens, which would produce stronger offspring and more offspring providing the beekeeper with more and stronger colonies in the spring. This strategy of division of the strong hives in the spring and killing the weak hives in the fall is a strategy to improve the overall survival qualities (both genetic and behavioral) in bees. In addition to removing bees that may be genetically inferior or behaviorally disadvantaged it is entirely possible that this technique of beekeeping also killed the very pests and diseases. It is possible to interrupt pest and disease cycles with periodic destruction of weaker hives

On pasture, it is important to have locations for wild pollinators to nest and create their hives. Hedgerows are an excellent nesting site for wild pollinators, and can be placed between fields and along the riparian zones of stream and pond sides. It is relevant to note here that a plastic queen cup, artificial insemination by a needle, and a regular regime of chemical powders and liquids selects for stronger pests and diseases and honeybees dependent on artificial insemination and chemicals.

Basic beekeeping equipment for observing and harvesting include:

1. Smoker.
2. Capping knife.
3. Extractor.
4. Personal protective clothing.

Direct honey products include:

1. Honey and fermented honey alcohol.
2. Propolis.
3. Wax (comb).
4. Royal jelly.

10.2 Wild pollinator insect cultivation

By using natural ecological practices, natural ecological species can survive and provide an important function in the environment. In a holistically designed landscape, there will likely be wild populations of pollinator insects, because the environment is conducive to their existence.

10.3 Undesirable insect control

A.k.a., Pest control

There are insects that are generally considered undesirable or less desirable on the landscape. There are ways of reducing these "pests" on the landscape to a level where they do not pose a significant irritation problem and contribute to the spread of disease. Biting insects and disease carrying insects must generally be controlled for. Common undesired insects (around human and animal habitation) include, but may not be limited to:

1. Mosquitoes - an irritation and carriers of disease. These insects bread in standing water. Mitigation techniques include:
   A. To reduce the spread of these insects, do not leave standing water on architecture or landscapes. Mosquito eggs can't survive in water with a current, so stagnant ponds are ideal mosquito breeding grounds. Mosquitoes need 7-12 days to lay and hatch eggs, and standing water in the rain garden will last for a few hours after most storms. Mosquitoes are more likely to lay eggs in bird baths, standing water in drainage ditches, and clogged roof gutters.
   B. Introduce mosquito predators to standing water bodies. Fathead minnow populations reproduce frequently and feed on mosquito larvae, making them great candidates for mosquito control. Also rain gardens attract dragonflies, which eat mosquitoes.
   C. Mosquitoes can be captured by traps. The traps are designed to attract the mosquitoes using attractants that mimic human breath (e.g., carbon dioxide produced from propane, octenol).
2. Tics - an irritation and carriers of disease. These insects are found in the wild and on wild animals. Mitigation techniques include:
   A. Fencing to exclude these wild animals from

pasture may reduce the tic population.
   B. Tics cannot be caught by traps.
3. Flies - an irritation to cattle and humans. Animals make manure, and manure attracts flies and other insects. Flies will breed on rotting organic matter that is not buried or made into a healthy compost pile. Flies can also breed in drains and on food rotting inside architecture. It is possible to reduce flies through:
   A. Flies can be captured by traps. Trapping can be done through sticky tape or vacuum.
   B. The cultivation of predators to flies can reduce fly populations. The rotation of different animals on pasture, particularly those that consume insects, will likely reduce files. Birds prey on flies. Parasitic wasps, are another natural predator of flies (but they don't bother people or animals). They lay their eggs in fly pupae, thereby eliminating flies before they ever have a chance to hatch.
   C. Cleaning up a landscape:
      1. Mounding manure by putting the manure in a large enough pile to allow it to heat up. The heat makes it a less hospitable spot to lay eggs, and will eventually produce a finished compost.
      2. Spreading manure in a thin layer in our pasture (using a manure spreader). This also helps to fertilize the grass.
      3. Dragging the pasture (with a tractor/drag) to break up manure piles, dry them out, and further reduce places for flies to lay eggs
4. Cockroaches - an irritation and carriers of disease. Cockroaches will breed on rotting organic matter that is not buried or made into a healthy compost pile. Cockroaches can be killed by caught by traps and killed by insecticide. Architecture can be effectively sealed to cockroach infestations.
5. Ants - an irritation. Ants can be killed by insecticide and boiling water. Ants are decomposers when it comes to their role in ecological service recycling. Architecture can be effectively sealed to ant infestations.

11 Controlled micro-organism cultivation

A.k.a., Microorganism cultivation.

Microorganisms can be used/cultivated to produce foods, medicines, and other nutritional elements. The two primary types of microorganisms cultivated to produce nutritional elements are:

1. Bacteria.
2. Fungi.

There are a wide variety of food-related products that can be made by micro-organism cultivation, including but not limited to:

1. **Cultured oil:** Oil cultures via bacteria. The bacteria convert sugars (found in plants) into fats. Cultured oil is the output of an oil culture using bacteria. Here, a group of microorganisms (a.k.a., oil culture) consume natural plant sugars, and transform those plant sugars into fats. The fats are then pressed (note: similar to pressing an olive to extract olive oil). The pressed oil is then separated, filtered, and put in a container. The sugars can come from almost any plant source high in sugar (e.g., beets, sugar cane, etc.). Effectively, a carbon source is needed for the bacteria to transform into fat, and that carbon source most efficiently comes from plants that photosynthesize and store "energy" as sugar.
2. **Cultured alcohol:** Alcohol cultures via bacteria. The bacteria convert sugars (found in plants) into fats.
3. **Cultured acid:** Acid cultures via bacteria. The bacteria convert sugars (found in plants) into acids.

Microorganisms can be used to convert one "food" into another, and for food preservation. For example,

1. Grains can be converted into bread.
2. Grains can be converted into beer.
3. Fruit can be converted into wine.
4. Leaves can be converted into kimchee/sauerkraut.
5. Meat can be converted into fermented/ripened meat (note: this includes fish).

11.1 Fermentation and concentration of micro-organism cultivation products

There are two types of fermentation:

1. Controlled fermentation.
   A. Fermentation (a biological process of micro-organism digestion) makes alcohol and

distillation (a chemical process of heating) makes liquor by concentration of the alcohol.
2. Uncontrolled fermentation (a.k.a., unsafe fermentation).
   A. Uncontrolled fermentation makes pathogens and unsafe environments.

There are a variety of microbial hazards associated with fermented food, including microorganisms and fungi. Growth of potential dangerous microorganisms can be controlled by appropriate environments and formulations (salt, curing agents, sugar types, starter cultures, ripening temperature, etc.).

12 Cultivation decomposition breakdown pathway

A.k.a., Organics disassembly pathway, organic decomposition, organic waste breakdown.

In nature, the elements in combination with a microbe rich environment breaks down (eats/decompose) specific materials. Organic decomposition serves as a pivotal breakdown pathway for waste outputs originating both from urban centers and production processes. In the context of the habitat, organic waste, including food scraps and yard debris, constitutes a significant portion of solid waste. Effective organic decomposition, through processes such as composting or anaerobic digestion transforms them into valuable resources like compost and biogas.

Organic waste originates from a variety of sources, including but not limited to:

1. Agricultural cultivation from direct cultivation of animals and plants. All cultivation operations produce organic waste. Forestry activities generate organic waste in the form of logging residues, branches, and bark. Fisheries and aquaculture operations produce organic waste in the form of fish offal and by-products. Urban non-agricultural vegetation cultivation (e.g., gardens and urban greenery) generate organic waste such as tree trimmings, grass clippings, and prunings.
2. Food services:
   A. Food processing generates organic waste streams from the processing and packaging of food products.
   B. Restaurants, cafeterias, and food service establishments generate significant quantities of organic waste, including food scraps, peels, and leftovers.
   C. Residential homes including kitchens and gardens contribute to organic waste with food scraps, yard trimmings, and organic materials.
   D. Food storehouses (supermarkets/grocery stores in the market-State) will discard expired food items (or, unsold items in the market), leading to organic waste generation.
3. Medical services may produce organic waste from patient care and pharmaceutical disposal.
4. Educational services may produce organic waste from education and research activities.
5. Construction and demolition sites output organic materials for decomposition including but not limited to: cellulose material (e.g., wood and paper) and plant debris.
6. Water sewage and wastewater treatment facilities

handle organic matter from sewage, wastewater, and sludge treatment processes.
7. Paper technology production generates organic waste, including wood chips, bark, and pulping residues.

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TABLES

Table 48. *Examples of grazing systems: Two-Pasture - Switchback System*

			G	*Graze*		*Rest*
PASTURE	M A M J	J A S O	N D J F	M A M J	J A S O	N D J F
1	G		G		G	
2		G		G		G

Table 49. *Examples of grazing systems: Three-Pasture - One Herd System*

PASTURE	A M J J A S O N D J F M			A M J J A S O N D J F M			A M J J A S O N D J F M		
1	G		G		G		G		G
2		G		G		G		G	
3			G		G		G		G

Table 50. *Examples of grazing systems: Three-Pasture - Two Herd System*

PASTURE	A M J J A S O N D J F M				A M J J A S O N D J F M				A M J J A S O N D J F M			
1		G	G		G	G		G	G			
2			G	G		G	G		G	G		
3				G	G		G	G			G	G

Table 51. *Examples of grazing systems: One Herd - Multi-Pasture System*

PASTURE	A		M		J	J		A	S		O		N	D		J		F	M		A
1	G							G							G						
2		G							G							G					
3			G							G							G				
4				G							G							G			
5					G							G							G		
6						G							G							G	
7							G							G							G

Table 47. *Harvest succession timeline. This is a table showing spatial and temporal layout of plants to be used for planting. When planting a landscape the following chart may be used. This chart ensures that a farmer is covering all the possible strata for the 5-100 years. The columns are time durations in growth-stage categories. The rows are the elevation layer location in space for the pants. It is possible to develop a 3D plan (i.e., a 3D planting plan, 3D model) that covers all of the strata for more than 50 years. Plant growth is subsequently observed, human removal of specific woody species may occur, and the chart can be continuously adjusted as needed. Avocado and ginger are given as examples. In concern to avocados, a farmer knows that for the best quality avocados, there can be no other plants that are emergent strata in the 5-to-20-year mark and take up the same 3D space as an avocado tree, or don't do well in its soil (i.e., avocado at years 5-20 will take up a specific location in 3D space, and no other plant can reside there). Its residence there for a long duration of time will likely influence what other plants can be grown in the surrounding area.*

	Placenta 1		Placenta 2	Secondary 1	Secondary 2	Climax		
Time till harvest:	45-90 days	90-120 days	120-180 days	180-365 days	2-3 years	3-5 years	5-20 years	20-100 years
Emergent							Avocado ⟶	
High								
Medium								
Low	Ginger ⟶	⟶						
Ground cover								

TABLES

Table 52. *A single alley-cropping two-dimensional landscape chart showing two rows (in dark gray) and four rows in the alley. The woody crops are primarily planted throughout the first two rows shown in dark gray. However, over time, trees in some rows may be culled and trees may also be planted in alleys. This is a simplified example showing the row an column separation of plants over a 2D landscape with low-quality stratification detail. This table shows 2 woody crop areas and an alley primarily filled with perennial grasses, and scattered with other plants in a manner that works for the animals and humans.*

STRATIFIED	TREE & GRASS	STRATIFIED	TREE & GRASS	STRATIFIED	TREE & GRASS	STRATIFIED	TREE & GRASS	STRATIFIED	10 meters in width
Tumeric and cassava every 15cm									
Raspberry Mulberry Avocado Acacia Banana	Mulberry	Raspberry Mulberry Moringa Acacia	Mulberry	Raspberry Mulberry Coffee REd cedar Acacia Banana	Mulberry	Raspberry Mulberry Moringa Acacia	Mulberry	Raspberry Mulberry Acacia Banana	1 Meter woody-crop area
Ginger every 15cm									
Perennial grasses	Clover	Radish	Perennial grasses	Perennial grasses	Perennial grasses	Perennial grasses	Perennial grasses	Perennial grasses	2 meter woody-crop area
Perennial grasses	Perennial grasses	Perennial grasses	Perennial grasses	Blackberry	Perennial grasses	Perennial grasses	Perennial grasses	Perennial grasses	2 meter alley
Perennial grasses	Perennial grasses	Clover	Perennial grasses	Perennial grasses	Perennial grasses	Perennial grasses	Blackberry	Perennial grasses	2 meter alley
Perennial grasses	Perennial grasses	Perennial grasses	Tomatoes	Potato	Perennial grasses	Perennial grasses	Perennial grasses	Perennial grasses	2 meter alley
Tumeric and cassava every 15cm									
Rasberry Mulberry Lemon Red cedar Acacia Banana	Mulberry	Mulberry Maringa Acacia	Mulberry	Line Acacia Mulberry Banana	Mulberry	Mulberry Moringa Acacia	Mulberry	Mulberry Red cedar Acacia Avocado Banana	1 Meter woody-crop area
Ginger every 15cm									
8 Meters in distance									

TABLES

Table 53. *The following table shows the set of hazards, compatible planting understory types, and food sources for different animal species. These represent constrictions/limitations in a holistic cultivation environment for different species of livestock.*

Boundaries and risks of holistic cultivation livestock					
Species	Hazards		Compatible planting understory types		Food source (simplified)
Livestock species	**Damage young trees**	**Scratch or dig** (damage roots, plants, or expose bare soil)	**Pasture only**	**Diverse perennial crops**	**Consumes**
Cattle	Yes		Yes		Grasses
Sheep	Yes		Yes		Grasses and woody matter
Goats	Yes		Yes		Grasses and woody matter
Llama (or other)					
Hogs	Yes	Yes	Yes		Woody plants, tubers, and protein
Chickens		Yes	Yes		Insects, amphibians, grain
Ducks & Muscovies				Yes	Insects, amphibians, grain
Geese				Yes	Insects, amphibians, grain
Turkey		Yes	Yes		Insects, amphibians, grain
Guinea fowl				Yes	Insects, amphibians, grain

Table 54. *Table showing the holistic functions of different species of livestock.*

Holistic cultivation functions						
Species	Functions					
Livestock species	**Mow & graze**	**Clear brush**	**Insectivorous**	**Till**	**Weed grass only**	**Clean drops**
Cattle	Yes					
Sheep	Yes	Some breeds				
Goats	Yes	Yes				
Llama (or other)						
Hogs	Yes			Yes		Yes
Chickens	Yes		Yes	Yes		Yes
Ducks & Muscovies	Yes		Yes		Yes	
Geese	Yes				Yes	
Turkey	Yes		Yes			Yes
Guinea fowl			Yes			

TABLES

Table 56. *Livestock land carrying capacity. (INCOMPLETE)*

Holistic cultivation functions						
Species	**Area Types**				**Requirements**	
Livestock species	**Soil Type**	**Feed Amount**	**Feed Quality**	**Water Amount (liters/day)**	**Land Area Required**	**Water Area Required**
Cattle	good			56-76	1-1.5 cows per .4 hectare	Supplemental in pasture
Dairy Cows	good			76-114	1-1.5 cows per .4 hectare	Supplemental in pasture
Sheep				7-11		
Goats				7-11		
Llama (or other)				?		
Hogs				1.8 - 5.6		
Chickens				~.4		
Ducks & Muscovies				1		
Geese				1.6 - 3.9		
Turkey				?		
Guinea fowl				?		

Table 55. *Empty table showing the measurements of different animal species (livestock) in terms of their nutrient values. The same table will work for plants and fungi.*

Nutrient values of polycultured animals.							
		Beef (cut specific)	**Chicken (specific)**	**Lamb (cut specific)**	**Pork (cut specific)**	**Sheep (cut specific)**	**Total**
Nutrient type:	**Measurement**						
Macro-nutrient	**Units**	**V/100g**	**V/100g**	**V/100g**	**V/100g**	**V/100g**	**V/100g**
Water	*g*						
Carbohydrate	*g*						
Protein	*g*						
Ash	*g*						
Energy	*kcal*						
Energy	*kj*						
Lipids	*g*						
Vitamins							
Vitamin A	*mg*						
Vitamin E	*mg*						
Vitamin K	*mg*						
...							
Minerals							
Calcium	*mg*						
Magnesium	*mg*						
...							

TABLES

Table 57. *Empty table showing the measurements of different plant species in terms of their nutrient values.*

Nutrient values of polycultured plants.									
		Grass	Chestnut	Apple	Hazelnut	Raspberry	Currants	Grapes	Total
Nutrient Type:	**Measurement**								
Macro-nutrient	**Units**	**V/100g**	**V/100g**	**V/100g**	**V/100g**	**V/100g**	**V/100g**	**V/100g**	**V/100g**
Water	*g*								
Carbohydrate	*g*								
Protein	*g*								
Ash	*g*								
Energy	*kcal*								
Energy	*kj*								
Lipids	*g*								
Minerals									
Iron (not hem iron)	*mg*								
Magnesium	*mg*								
...									
Vitamins									
Vitamin A	*mg*								
Vitamin E	*mg*								
...									

Life Support: Food Service System

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Version Accepted: 1 April 2024

Acceptance Event: *Project coordinator acceptance*

Last Working Integration Point: *Project coordinator integration*

Keywords: Food service system, feeding service system.

Abstract

The nutrition service system of a habitat provides food-related services that fulfill the needs of the inhabitants. The cultivation and service of food is necessary for humans for critical reasons related to sustaining life, growth, and overall health. The nutrition service necessarily considers important factors in nutrition to be sufficiency (human-user need), dietary preferences, sustainability, and the well-being of the inhabitants.

Graphical Abstract

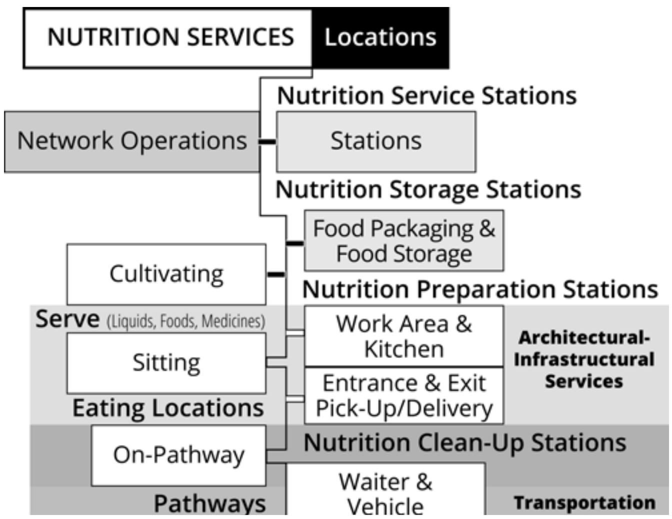

Figure 5. *Image depicts operation of a nutrition service system for a habitat service system.*

1 Food service overview

A.k.a., Nutritional service system overview.

A food service system involves at least the following operations:

1. **Food cultivation** (for species-specific nutrition).
2. **Food transport and delivery** (as appropriate).
3. **Food storage** (to preserve nutrition, safety, and flavor).
4. **Food processing** (to prepare food for direct consumption, or mixing into a recipe and directly consuming).
5. **Food packaging** (to prevent contamination and penetration by other organisms).
6. **Food consumption** (to restore the body and provide waste to be appropriately, materially, re-cycled).

The nutrition service system provides for the preferential nutrient needs of all human individuals. The nutrition system of a habitat encompasses various stages and physical stations:

1. **Food cultivation service** system sourcing.
2. **Food storage stations** - storage of food products (a.k.a., food resources) from the cultivation service system).
   A. Storage for raw food materials.
   B. Storage for intermediary food products.
   C. Storage for final food products.
3. **Food manufacturing stations** - packaging for storage and manufacturing for prepared food products. The InterSystem team prepares food for the food preparation stage, where both end users and InterSystem team members use it to prepare final food substances.
4. **Food preparation stations** (a.k.a., kitchens) for food products.
   A. **Self-preparation stations** for food products - self-preparation conveys the concept of individuals taking care of their own needs without the direct assistance of InterSystem team members, similar to cooking for yourself at home or cooking in a public/common-access setting. The user acquires the food ingredients, prepares the meal and consumes it themselves and/or with others.
      1. **Home self-preparation stations** (a.k.a., home kitchens and kitchenettes).
      2. **Common-access preparation stations** (a.k.a., self-service kitchens, self-preparation kitchen, self-service stations).
         i. Location specific:
            1. Self-preparation and eating area are the same location outside residencies (a.k.a., themed, non-home self-preparation and eating locations). A barbeque area, where food is barbequed and then eaten locally, is one example of this.
            2. Self-preparation and themed eating areas are different locations outside residencies. In other worsds, the user prepares food at one location (a kitchen) and then takes it, and eats it, at another location (e.g., eats it at a picnic location).
         ii. Time specific:
            1. Scheduleable - personally scheduled common access preparation and/or eating area.
            2. Non-schedueable - common access non-scheduleable preparation and/or eating area.
   B. **InterSystem team preparation stations**

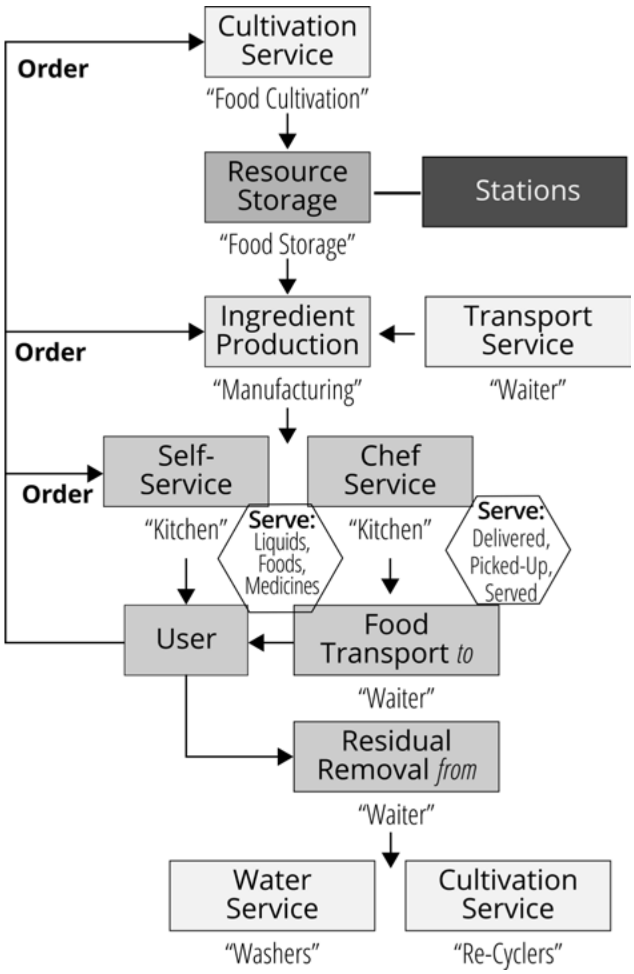

Figure 6. *Simplified sequence diagram for the nutrition service system.*

(a.k.a., **restaurants, cafeterias, etc.**) - the InterSystem team prepares food for users.
   1. Food prepared locally, where the user will eat (e.g., a restaurant-like location, where there is a kitchen and dining area).
   2. Food prepared for pick-up or delivery.

5. **Ordering stations and interfaces** - are the locations and interfaces used to order food.
   A. There may be life-phase foods that are restricted for ordering by those in specifically younger phases of life: Alcohol (and some other consciousness altering substances), for instance, are a normal part of adult social interaction, but these foods are not appropriate for individuals in the childhood phase of life.
6. **Pick-up stations** (Read: pickup-locations) - are locations where food resources and/or prepared food items are picked-up by end users**.**
7. **Eating locations** (a.k.a., dining and social spaces).
   A. Home dining rooms and areas.
   B. Common InterSystem team food-service provided eating areas (inclusive of delivery, take-away, and self-serve cafés/restaurants).
      1. Scheduleable - personally scheduled common access eating area serviced by the InterSystem team (e.g., appointment only restaurants).
      2. Non-schedueable - common access non-scheduleable eating area (e.g., habitat nutrition team serviced cafés/restaurants).
8. **Organic and mineral waste and recycling service system** (a.k.a., the cultivation, land and water service systems). This service includes composting and re-cycling.
9. **Transportation system** for food resources/ products - the serving, collection, and general movement of the food (i.e., food transport and residual collection).
10. **Computational, architectural, and power systems** are required.

2 Feeding behavior

Feeding is the act/behavior of an organism when it seeks and consumes, digests, and excretes chemical-biological material inputs. An animal, in order to eat, must follow three initial stages and one post stage - food must be acquired, prepared, and assimilated, and then, the leftovers and metabolic by-products must be excreted.

The stages of feeding behavior are:

1. **Acquisition** - get physical food constituents.
   A. **Location of acquisition** - location where and when humans acquire the raw inputs for food.
2. **Preparation** - prepare (sometimes not necessary) physical food constituents. Note that heat destroys some nutrients as well as dentures fat and protein. Here, there is processing and then there is ultra processing.
   A. **Location of preparation** - location where and when humans food is prepared.
3. **Consumption (a.k.a., assimilation)** - ingest and absorb the nutrients and allow specific microorganisms in specific places [in digestion] to absorb the nutrients. Digestion means to take in, assimilate as much as appropriate, and let go of the rest.
   A. **Location of acquisition** - location where and when humans can get their fulfillment needs for nutrition met.
4. **Excretion** - deposit outputs (undigested food and excretion products) exterior to the body.
   A. **Location of acquisition** - location where and when humans excrete the by-products of digestion and metabolism.

All food goes in through the mouth, the first organ of digestion. The mouth is a domain that each individual has complete and total control over (in regards to):

1. What goes in.
2. When it goes in.
3. How often it goes in.
4. The environment where the food is taken in.
5. What happens to it in the mouth.

The essential questions in terms of food cultivation/ production and feeding behavior are:

1. What do we cultivate so we flourish (with energy and flow), and do not get chronic diseases?
2. How do we eat so we flourish (with energy and flow), and do not get chronic disease?
3. What lifestyle and incentives encourages good, nutritious food choices and appropriate feeding times and timing?

4. What habitat support structure encourages good social interconnection, and privacy, where desired, when eating?

When calculating for food, for users, it is important to identify:

1. Food type.
   A. What is actually eaten?
   B. What is demanded to be eaten?
   C. What is the nutrient quality of what is eaten?
2. Food quantity (mass and volume).
   A. How much of what is demanded, is eaten?
   B. How much is eaten?
3. Food [meal] frequency.
   A. How often is there eating?
4. Food cultivation tasks and effort (service and energy).
   A. What materials, energy, and labor does it take to cultivate what is eaten?
5. Food preparation tasks and effort (service and energy).
   A. What materials, energy, and labor does it take to produce the final product that is eaten?
6. Food delivery tasks and effort (service and energy).
   A. What materials, energy, and labor it take to deliver what is to be eaten and to take away what was not eaten?
7. Food clean-up tasks and effort (service and energy).
   A. What does it take to clean-up after eating at the location where food was processed and eaten?
8. Food cycling tasks and effort (service and energy).
   A. What materials, energy, and labor it take to cycle (Read: up-cycle to other animals, and down-cycle to soil) what was not eaten?

3 Food as nutrition

Organisms need nutritional fulfillment (i.e., organisms need food). Food is orally in-taken matter, digested and absorbed through some functional organ(s), and partially excreted. Food is orally in-taken matter, composed of chemico-logical and bio-logical inputs. The purpose of eating is to acquire (as needed body inputs) essential nutrients and including fats and proteins, and vitamins and minerals (i.e., to acquire food). An essential nutrient is a vitamin, mineral, fatty acid, or amino acid required fro normal body functioning that either cannot be synthesized by the body at all, or cannot be synthesized in amounts adequate for good health, and thus, must be obtained from a dietary source. Humans eat because it is enjoyable and sociable, but also because organisms need to acquire certain nutrients without which they will get diseases and/or die. For example, unless humans get retinol, they will get eye disease; unless humans get vitamin D, they will get rickets or viruses (etc.). Each nutrient that a humans need, there is a reason for it. Food is that which nourishes us and exists in contrast to empty calories/mass, which has been produced for trade (Read: commodity exchange "value") and entertainment. Nutritional fulfillment allows for the optimal functioning of all organisms, humans and plants alike. In concern to food, there is the idea of a species appropriate, species specific dietary framework for eating. Humans need a diet with enough energy and nutrition for each day's activities (with the exception of fasting days). Different organisms given different environments have different nutritional make-ups. For humans, the purpose of eating is to acquire (as needed body inputs) essential nutrients, including fats and proteins, and vitamins and minerals.

> **NOTE:** *Cultivation of food for animals other than humans is known as "feed".*

Effectively, food provides the following three functions for the body; it is:

1. The building blocks of a body's structure.
2. A means of energizing (powering) the body.
3. A source of information for the body.
4. Social connection.

> **INSIGHT:** *Eating what we are biologically designed to eat is going to give us optimal nutrition. Species have a specific, evolutionary, biological appropriate, species-specific diet.*

3.1 Parameters of food

A basic nutrient analysis can be done on all food, plants, animals, and fungi, it can also be done for whole pastures/landscapes. Nutritional analysis can be done on any organism to reveal its breakdown of vitamins, minerals, and other bio-chemicals. In the early 21st century, plant sourced foods are far more variable in their nutrient content than animal sourced foods; because, of their growing conditions. However, animal sourced foods will also be varied in their nutrients, though not as much as plant-source foods, because of the varied nutrients in the plants animals eat. In concern to food, it is important to note here that the scientific breakdown of molecules may not equate to how much nutrition any given human may acquire from its consumption. For example, a nutrient may be bound up by an anti-nutrient, making it unavailable for sufficient digestion and absorption. Or, an organism may have a damaged digestive system, which could reduce nutrient uptake and utilization.

Food is ingested mass. "Ingestion" refers to the process of taking in food or other substances through the mouth, which is the initial step in the digestion and absorption of nutrients by organisms. Ingestion is the act of consuming or eating food. If food is "ingestion" mass taken in by the mouth, then every type of organism has a specific diet in terms of the:

1. The amount of mass taken in.
2. The makeup of the mass.

In order to provide sufficient and appropriate food to meet human requirements, the following food parameters must be accounted for (i.e., parameters for food include, but may not be limited to):

1. **Mass (g or kg):**
   A. The mass of a food is typically measured in units of grams (g) and kilograms (kg).
   B. Supplements are typically measured in milligrams (mg, 1/1,000 of a gram) and micrograms (μg, 1/1,000,000 of a gram).
2. **Water Content (%):**
   A. The water content of food is typically measured in percentage (%). This measurement represents the amount of water present in the food compared to the total weight of the food.
3. **Volume:**
   A. The volume of a food is typically measured in units such as milliliters (mL), liters (L), cubic centimeters (cm^3 or cc), cubic meters (m^3), fluid ounces (fl oz), or teaspoons/tablespoons (tsp/Tbsp).
4. **Calories (Kcal):**
   A. A calorie (cal) is a unit of "energy" used in nutrition to quantify the energy content of food and the energy expenditure of the human body. The energy content of food is typically expressed in kilocalories (Kcal). A calorie (cal) is defined as the amount of heat required to raise the temperature of one gram of water by one degree Celsius in a bomb calorimeter. One food calorie is equal to 1000 calories of heat energy (i.e., 1 Cal = 1kcal).A bomb calorimeter is a laboratory apparatus designed to measure the energy content of food by complete combustion. A bomb calorimeter is a closed system and does not represent what any given human would do with a given macro nutrient. There is no receptor for calories in the body. The body does not know what a calorie is. Calories are fine for comparing energy content of food products, but not really very useful for scientific work. For scientific applications an energy unit called the joule (J) is used.
   B. Caloric density (CD) is typically measured in kcal (kilocalories) per unit weight (kg, in this case). Caloric density indicates the number of calories present in a particular weight or volume of food. Here, density refers to the concentration of calories within a given amount or volume of food. Foods with higher caloric density contain more calories per unit of weight or volume compared to foods with lower caloric density.
   C. In practical application, a calorie is another word for a macro-nutrient.
5. **Macro-nutrient profile (grams or calories):**
   1. **Proteins (a.k.a., amino acids)** - consist of atoms of carbon (C), hydrogen (H), oxygen (O), nitrogen (N), and sometimes sulfur (S). Proteins are composed of amino acid chains (a.k.a., amino acid sequences). All protein is not equal for human biomolecular physiology:
      i. Digestible safe proteins.
      ii. Toxic proteins and amounts.
   2. **Lipids (a.k.a., fats, fatty acids, oils)** - primarily composed of hydrocarbons, chains of carbon (C) and hydrogen (H) atoms. All lipids are not equal:
      i. Digestible safe lipids.
      ii. Toxic lipids and amounts.
   3. **Carbohydrates (a.k.a., sugar, saccharides -** are composed of carbon (C), hydrogen (H), and oxygen (O) atoms. They are commonly arranged as chains or rings of carbon atoms with attached hydrogen and oxygen atoms, typically in a ratio of 1:2:1 (carbon, hydrogen, oxygen). All carbohydrates are sugar. All carbohydrates (sugar) is not equal:
      i. **Monosaccharides (a.k.a., single sugars, simple mono sugar):**
         a. Glucose.
         b. Fructose.
         c. Galactose.
         d. Etc.
      ii. **Dissacharides (a.k.a., double sugar, two sugars, two sugar carbohydrate):**
         1. Sucrose (a.k.a., table sugar) - 1 molecule of glucose and 1 molecule of fructose.

iii. **Polysaccarides (a.k.a., many-sugars, many-sugar carbohydrates):**
   1. **Digestible polycsaccarides** (i.e., many-sugars that can be digested).
      a. Digestible starch (note: most starch is digestible and is made up long chains of glucose molecules linked together).
      b. Glycogen (in mammals).
   2. **Indigestible polysaccarides (a.k.a., fiber; i.e., many-sugars that cannot be digested):**
      a. **Soluble indigestible polysaccarides (a.k.a., soluble fiber).** Resistant starch has some characteristics of soluble fiber since it can be fermented by beneficial bacteria in the large intestine, producing short-chain fatty acids that are absorbed.
      b. **Insoluble indigestible polysaccarides (a.k.a., insoluble fiber).** Resistant starch can be considered a type of insoluble fiber as it passes through the small intestine without being broken down and absorbed (i.e., starch resistant to digestion).

6. **Micro-nutrient profile (primarily measured in milligrams or even micrograms):**
   A. **Vitamins (a.k.a., vitamin micronutrients):** Vitamins are non-macronutrients and non-mineral nutrients that are essential for life and not manufactured by the body. The two essential qualifiers for a vitamin (a two-fold simultaneous criteria) are:
      1. Essential for life, and
      2. Not manufactured by the body (or by the body in sufficient quantity to sustain optimal well-being of the body).
   B. **Non-vitamins (a.k.a., non-vitamin micronutrients):** There are two types of consumable non-vitamin nutrients:
      1. Nutrients that are not essential for the life of the body, and not manufactured by the body,
      2. Nutrients that are essential for the life of the body, and manufactured by the body in sufficient quantities.
7. **Mineral profile (primarily measured in milligrams or even micrograms):**
   A. All minerals are not equal. Some minerals are dangerous for humans to consume, including all heavy metals and all radioactive minerals.
   B. Note that minerals could be considered part of the micro-nutrient profile of food.
8. **Biological profile (primarily measured in milligrams or even micrograms):**
   A. Peptides (a.k.a., protein hormones, protein messengers, protein chemical messenger, protein signaling messengers).
   B. Bioactive lipids (a.k.a., lipid signaling messengers not of the lipid hormone category).
      1. Lipid hormones (a.k.a., lipid messengers, lipid chemical messenger, lipid signaling messengers).
      2. Other bioactive lipids (e.g., sphingolipids, phospholipids, eicosanoids (such as prostaglandins and leukotrienes)
   C. Enzymes.
   D. Nucleic acids (DNA and RNA).
   E. Biome (i.e., bacteria, fungi, and virus ecology).
   F. Note that biologics could be considered part of the micro-nutrient profile of food.
9. **Flavor profile.**

3.1.1 Biologics

Biologics are composed of some combination of organic compounds belonging to one of four classes of molecules:

Large macromolecule - small subunit molecule

1. Carbohydrates - sugars.
2. Lipids - fatty acids
3. Proteins - amino acids.
4. Nucleic acids - nucleotides

Proteins, nucleic acids, and most carbohydrates (the polysaccharides) are macromolecules formed by the joining (polymerization) of hundreds or thousands of low-molecular-weight precursors.

3.2 Essential nutrients

A.k.a., Essential macro- and micro-nutrition.

All organisms have a quantity and quality of essential nutrients in order to maintain optimal functioning. Herein, essential means required for life and must be acquired/consumed from outside the body. All organisms have a bio-regional environment, including climate and available resources in which they are likely to thrive and/or survive. Fundamentally, the diet that humans require is one that is nutritionally complete, and without unnecessary additives. Humans absolutely require protein, fat, vitamins, and minerals for survival. It is important to note here that although carbohydrates may (or may not) have benefit, carbohydrates are not classified as an essential nutrient; because, the human body can get glucose from other nutrients on an as needed basis (through gluconeogenesis). Also, fiber is not an essential nutrient for human life. Fiber is not considered an essential nutrient because it doesn't meet the criteria of being needed for life or growth.

The classification of nutrients into "essential" and "non-essential" categories is based on whether the human body is capable of synthesizing them in sufficient quantities. Essential nutrients are those the body cannot produce at all, or not enough of, and therefore must be obtained through the diet. On the other hand, non-essential nutrients can be synthesized by the body. However, the distinction becomes less clear when considering that many individuals may not synthesize adequate amounts of certain non-essential nutrients due to genetic variations, health status, age, or lifestyle factors. This complexity suggests that for some people, what is typically classified as a non-essential nutrient may, in practice, become essential to obtain through dietary sources to maintain optimal health. In other words, there are some nutrients that are considered "non-essential", because humans make them; however, many humans do not make enough, thus muddying the water in terms of what is and is not essential.

Humans must consume a set of essential nutrients to survive and thrive:

1. **Essential macro-nutrients:**
    - A. **Essential proteins (a.k.a., essential amino acids, EAAs)** - amino acids that the body does not make and must be acquired from diet/ food. There are eight essential amino acids, which, when combined in various proportions, form complete proteins. Complete proteins, containing all essential amino acids in sufficient quantities and appropriate ratios required by humans, are primarily found in animal-derived foods.
        1. The eight essential amino acids are: Tryptophan, lysine, methionine, phenylalanine, threonine, leucine, isoleucine, valine.
    - B. **Essential fats (a.k.a., essential fatty acids, EFAs**) - lipids that the body does not make and must be acquired from diet/food. The essential fats in the form that humans need them come from animal foods.
        1. The essential fats are: Eicosapentaenoic acid (EPA), docosahexaenoic acid (DHA), conjugated linoleic acid (CLA), arachidonic acid (ARA). There are actually essential fats that are not generally considered essential, such as stearic acid.
    - C. There are no essential carbohydrates.
2. **Essential micro-nutrients (a.k.a., 13 vitamins):**
    - A. **Fat soluble vitamins (lipid co-factor molecules).**
        1. There are four known fat soluble vitamins:
            - i. **Vitamin A: Retinol types:**
                1. Retinol (the active natural form).
                2. Retinal.
                3. Retinoic acid.
            - ii. **Vitamin D: Calcitrol types:**
                1. Calcitrol (steroid hormone made from cholesterol; the active natural form).
                2. Ergocalciferol (D2).
                3. Cholecalciferol (D3).
            - iii. **Vitamin E: Tocopherol and tocotrienol types:**
                1. Alpha-tocopherol,
                2. Beta-tocopherol.
                3. Gamma-tocopherol.
                4. Delta-tocopherol tocotrienols.
                5. Alpha-tocotrienols,
                6. Beta-tocotrienols.
                7. Gamma-tocotrienols.
                8. Delta-tocotrienols.
            - iv. **Vitamin K: Naphthoquinone, phylloquinone (a.k.a., phyloquinone, K1) types:**
                1. Phylloquinone (active natural form)
                2. Phytonadione (synthetic K1)
                3. Menaquinone (natural K2), and K2 homologues:
                    - a. Menadione (K4; synthetic) through MK13 (synthetic).
    - B. **Water soluble vitamins.**
        1. There are eight known water soluble vitamins:
            - i. **The nine B vitamins (water co-factor molecules).**
                1. **Vitamin B1: Thiamine.**
                    - a. A thiazole derivative.
                    - b. Homologues: Thiamine diphosphate (TPP), thiamine mononitrate, thiamine hydrochloride benfothiamine, etc.
                2. **Vitamin B2: Riboflavin.**
                    - a. A flavin compound.
                    - b. Homologues: Riboflavin-5'-phosphate (flavin mononucleotide or FMN), riboflavin-5'-adenosine diphosphate (flavin adenine dinucleotide or FAD).
                3. **Vitamin B3: Niacin (nicotinic acid and nicotinamide).**
                    - a. Homologues: Nicotinic acid, nicotinamide, nicotinamide adenine dinucleotide (NAD), nicotinamide adenine dinucleotide phosphate (NADP).
                4. **Vitamin B5: Pantothenic Acid.**
                    - a. A derivative of β-alanine -- each has a substituted β-alanine linked to a β-mercaptoethylamine, which in turn is linked to a valeric acid side chain.
                    - b. Homologue: Coenzyme A (CoA)
                5. **Vitamin B6: Pyridine ring types**

(pyridoxal or pyridoxamine).

a. A pyridine compound -- each has a six-membered heterocyclic aromatic ring containing five carbon atoms and one nitrogen atom.

b. These two forms are converted within the body into their active coenzyme form, known as pyridoxal 5'-phosphate (P5P, PLP).

c. Homologues: Pyridoxal-5'-phosphate (P5P, PLP), pyridoxamine-5'-phosphate (PMP), pyridoxine.

6. **Vitamin B7: Biotin.**
   a. A sulfur containing compound -- each has a heterocyclic sulfur-containing ring fused with a ureido (also called imidazole) ring. Biotin has a long side chain that contains a valeric acid moiety.
7. **Vitamin B9: Folate.**
   a. A complex molecular structure characterized by a pteridine ring, a para-aminobenzoic acid (PABA) moiety, and a glutamate tail. This structure is distinct from other vitamins and compounds.
   b. 5-methyltetrahydrofolate (5-MTHF; the natural active form)
   c. Homologues: Folic acid (synthetic), tetrahydrofolate (THF; natural metabolite of folate).
8. **Vitamin B12: Cobalamin.**
   a. A complex cobalt-containing compound.
   b. Homologues: Methylcobalamin, adenosylcobalamin, hydroxocobalamin, cyanocobalamin.
   c. Three forms of B12 occur naturally in nature: adenasil, hydroxy, and methyl. Cyanocobalimin is an entirely synthetic form of B12 based on hydrogen cyanide.
9. **Vitamin C: ascorbic acid.**
   a. Ascorbic acid is a single chemical compound with the molecular formula $C_6H_8O_6$. It is an organic acid characterized by a six-carbon ring structure.
   b. Derivatives (not homologues) include mineral salts: ascorbates (such as calcium ascorbate, sodium ascorbate, ascorbyl palmitate, and other esterified forms).

3. **Essential minerals.**
   A. **Intracelluar minerals (a.k.a., cellular minerals)** - minerals found in cells in specific chemical forms, such as ions or complexes, that are compatible with cellular processes.
   B. **Raw minerals** - base minerals dissolved in drinking water. Raw minerals dissolved in drinking water that humans require are called "electrolytes" (or, electrolytic minerals). Technically, however, both types of minerals act like electrolytes.
4. **Essential biologics.**
   A. For example: peptides, hormones, steroids.

CLARIFICATION: *The naming system where vitamins are designated and identified using letters (such as Vitamin A, Vitamin B, Vitamin C, etc.) is known as the "vitamin nomenclature" or the "vitamin naming convention". This system assigns alphabetical letters to various vitamins, initially identifying them based on their discovery order or as distinct compounds with specific functions and characteristics within the realm of nutrition and human health. For instance, vitamins A, B, C, D, E, and K are some of the well-known vitamins classified under this naming convention. Some of these categories have multiple sub-types, such as the B category, which currently has eight (B1, B2, ...).*

NOTE: *A homologue refers to different chemical forms or variations of a specific nutrient that share a similar structure or function but may have slight differences in their chemical composition or properties. Some homologues are beneficial (expected by the body in the right amounts) and others harmful (not good for the body in any amount). Synthetic vitamins can be of concern. For instance, pyridoxine, which is a synthetic B6 homologue, has more recently been found to covert very little (<5%) and block pyridine ring receptors.*

3.2.1 The changing science around essential nutrients

There were once chemical compounds, such as B4, B8, B10, and B11, that were once thought to be vitamins, thus given numbers in the B-vitamin complex numbering scheme. However, they are no longer labelled as vitamins; because, they were discovered not meet the two criteria for the definition of a vitamin (Read: essential and not intrinsically produced). Vitamin B4 is a former designation given to several distinct chemical compounds, each of which at a specific time in science was thought to be a vitamin, and none of which now is currently considered a true vitamin: adenine, carnitine, choline, adenine, for example is still a critical component of energy regulation and found in our DNA and RNA, but is not a 'vitamin' anymore.

Also, it is important to realize that there can be negative outcomes supplementing with isolated vitamins when someone is already healthy and is sufficient in a vitamin. There can also be negative outcomes supplementing with synthetic and homologue forms of vitamins.

3.2.2 Recommended dietary allowance (RDA)

A.k.a., Recommended daily allowance (RDA).

States jurisdictions typically provide a recommended dietary allowance (RDA) per day (or, recommended daily allowance, RDA) value to the public in a policy document as the absolute minimum amount of a nutrient needed (per day) to prevent full blown deficiency under laboratory conditions. The RDA is not a target, it is a minimum. Also, RDA's are sometimes highly influenced by corporations who seek to sell more of their product(s). It is possible to set an RDA too low or too high. In studies using and succeeding with nutrients as intervention, they are almost always using 10 to 100x more than the RDA standard. Nutrient deficiencies can come from genetics, a poor diet, a non-optimal digestive system, etc.

CLARIFICATION: *It is possible to take to much of any vitamin, and overdose.*

Nutrient absorption, proportioning, and metabolism is affected negatively, in general, by stress of the following possible types:

1. **Physical stress** - e.g., exercise,movement against gravity, extreme temperatures, etc. Leads to physical fatigue (and then, mental fatigue).
2. **Emotional stress** - e.g., anger, fear, worry, trauma. Leads to mental fatigue, and then physical fatigue.
3. **Biochemical stress** - e.g., eating plant toxins, environmental toxin exposure, micronutrient deficiency, macronutrient deficiency. Leads to cellular fatigue, then mitochondrial fatigue.

3.3 Food and connection

When individuals hunt and forage from a landscape, they find easily that they have an interest [in the health] of that landscape, and in the organisms that navigate that landscape. When someone has a relationship with a landscape, because one experiences the acquisition of food from that landscape, then one has a vested interest in that place. The same goes for the organisms themselves, the harvesting and hunting of a species gives the "predator" a relationship with that species that someone who thinks ill of harvesters and hunters might not have. There is a saying among traditional hunters:

"People who hunt deer love deer more than people who think hunters shouldn't hunt deer because it is not nice ... who think deer shouldn't be hunted. Hunters who hunt deer really come to know deer deeper, like they know themselves. Some people struggle psychologically with how ecology works, in that organisms eat other organisms. That is nature."

Food, as a basic human needs, influences real-world relationships between people. When relaxed with other humans, the consumption of food among a social group can facilitate a sense of well-being, connection, restoration, and create a strong social bond. In many ways, the environment in which food is consumed has a significant impact on individuals' feelings about themselves, others, and internally, their own state of nutrient satiation. Sharing a meal with people will create a shared experience that makes them understand that you have a similar experience of the senses. "Good meals" in "good environments" can enliven human happiness, uplift human well-being, and provide for a state of healthy social sharing and discovering.

APHORISM: *A good meal will put [good] people in a good mood.*

3.4 Food and completeness

Organisms consume food in order to become complete and continue to function without listlessness and disease. Significantly sub-optimal nutrition will reduce the quality and length of life. Nutrition can be sub-optimal in at least the following ways:

1. It can have too many calories.
   A. It can have excess carbohydrates.
   B. It can have excess powders (i.e., to much of the composition of the food is in powdered form, likely, primarily from powdered grains).
   C. It can have any industrial [vegetable] fats (any beyond medicine is likely an excess).
2. It can have too few calories.
3. It can have too little [appropriate] fats.
   A. Too little fat will reduce satiation per meal.
4. It can have two little [appropriate] protein.
   A. Too little protein will cause the body to continue to seek more food until protein requirements are met.
5. It can be deficient in micro-nutrients.
6. It can have excess plant defense compounds.

And, having too much, or too little of anything may produce different phenotypes.

There are biological evolutionary factors also that likely influence a "species-specific" diet (which, is another name for food "consumption completeness"):

1. Morphology of the species and its digestive tract- The short length of the digestive tract (which is unable to extract nutrition from significantly fibrous foods, and the organism does not have to spend many hours a day eating to acquire enough volume).

   A. For example, the human digestive tract is ~40% smaller than a chimpanzee.
2. Acidity of each area of the digestive tract, particularly the initial digester or digester network - The acidity of the stomach.
   A. For example the human acidity is 'high' acidity near that of a scavenger).
3. Technology of the species - Tools using, allowing a tool using species to have smaller teeth and weaker mandibles.
   A. For example, humans can predate upon other sized mammals and fish, and cook the product with fire.

3.5 *Food as nutrition for humans*

STATEMENT: *We understand that what we feed our bodies plays a critical role in our state of physical and mental health. We recognize that eating a healthy diet is important not only for our own well-being, but for the well-being of the community and for our future generations. Consuming healthy meals is a requisite foundation for a vibrant future, and a healthy meal starts with healthy ingredients and a calm environment. We acknowledge that a healthy and high-quality diet is a necessity for individuals seeking to progress toward their higher potential. We recognize the inherent connections between the genetics of a particular food item, food cultivation practices, the freshness of food, the nutritional value of a food, and foods' ability to support individual's in achieving optimal health and well-being. We want to eat the healthiest, nutritionally dense and flavorful, and most optimal diet we can to optimize our functioning, optimize our germline (our offspring), minimize our diseases, and minimize our resource expenditures on sick-care. Choosing a bad diet, and harmful lifestyle habits, can over time make someone a burden on society, because they have become sick. Poorer quality nutrition and lifestyles lead to poorer health and lead to increased healthcare resource expenditures. Together, we seek the fitness to thrive and replicate on earth, with our off-spring having a higher human potential then ourselves. The behaviors and food consumption of the parents affects the offspring and influences their genetic potential. Individuals' decisions about their nutrition affect not only themselves, but the entire population. In community, we acknowledge individuals' taste preferences and nutritional parameter requirements.*

Animals thrive on nutrition. On earth, all physical entities need to feed off other physical entities in order to survive. Fundamentally, there is no life without death. All humans are homosapiens and all homosapien genetics are essentially the same, with minor differences. Essentially all humans have the same biochemistry -- the way we use and inter-convert nutrients is the same. Humans are a type of omnivore, as are most mammals. Omnivores usually specialize and lean more toward animals or plants. Humans are animal-based omnivores; in other words, they lean more toward acquiring their nutrition from animals. Although humans can have benefits from some vegetation, the bulk of the nutrients must come from animal products.

Optimizing the well-being of human beings requires optimization of:

- A species specific diet [of foods] including nutritious and naturally satiating foods.

There are three types of omnivores:

1. Carnivorous-omnivores (i.e., cats, dogs, and humans).
   A. Hypercarnivores eat a diet 90-100% composed of animals.
   B. Supercarnivores eat a diet 70-90% composed of animals.
2. Herbaceous-omnivores (i.e., plant-based omnivores; e.g., cattle and sheep).
3. General-omnivore (e.g., rats and pigs).

All life is sacred and moral human behavior relates to how humans look after and caretake the animals. The animals are honored by giving them a fantastic life, looking after them the best we can, and then to justify killing one of these beautiful creatures, we have to live a good life and do the right thing too. The focus is on optimizing life and well-being for life. Food is equivalent to vitality -- how the body exchanges energy with its environment. In community, we are thankful that they give their lives and in return we caretake them, make sure that they are healthy, that they too prosper and that they too have good lives. We look at animals as our cousins, our relatives, as everything alive on this planet.

INSIGHT: *There is what we need to thrive (the right amount of nourishing food), and then, there is what we can tolerate (survival foods).*

Effectively, humans get their nutrition from some ratio of two sources (Read: humans eat):

1. Animals who are perfectly designed to consume (safely and efficiently) biological ingredients from their environment and nourish their bodies.
2. Replicate natural biological processes to process plant food so that it can be consumed safely and ha available nutrition, such as, fermenting, soaking and sprouting, cook, grind, etc.

Nutritional food variables include, but may not be limited to:

1. What is eaten.
2. Quality of what is eaten.
3. Quantity of what is eaten.
4. How it is eaten.
5. When it is eaten (time of day).
6. Where it is eaten on the planet (in colder northern and southern hemispheres, or near the equator where there is more sunlight).
7. Environmental-psychological context during eating.
8. Functioning of the digestive system of the animal.
9. Genetics of the organism eating food.

The following are kingdoms/types of life that humans can eat:

1. Land animals (meat comes from wild animals and from animal stewardship; meat consumption is at the very least a 200,000 year practice among humanity).
2. Fish and other marine animals.
3. Plants.
4. Insects (entamophagy).
5. Fungi.
6. Bacteria.

Traditionally, there are four kingdoms of food:

1. Animals.
2. Plants.
3. Fungi.
4. Bacteria (& symbiotic cultures).

3.5.1 Food and the human genome

> **INSIGHT:** *Is there an evolutionary precedence for the species for the consumption of something (and/or the consumption of something a x current quantity); if there isn't, there might necessarily be increased caution.*

There are three genomes that together run the human body:

1. Human genome.
2. Mitochondrial genome.
3. Bacterial genome.

> **NOTE: A***ll three genomes affect the biochemical individuality of any one person.*

Food is both materiality that interacts informationally with all three genomes. A food is composed of more than just nutrients and our body takes in the nutrients and tries to dispose of those things that are bad. The interaction of these genomes creates over 4 million possible snips.

The human genome is expecting at least the following from its food:

1. Macro-nutrients:
   A. Amino acids (proteins, peptides).
   B. Lipids.
   C. Carbohydrates.
   D. Nucleotides.
2. Micro-nutrients:
   A. Vitamins.
3. Minerals (mineral nutrients):
   A. Salt.
   B. Others.

Nutrients are substances that must be consumed through a diet on some cyclical basis, and if they are not consumed, then the body will develop disorders/diseases. Supplements are called supplements because they supplement what humans try to get through natural foods (guided and/or directed via the intrinsic mechanisms generating taste and flavor). Supplements are equivalent to "insurance" for the physical body during times when there is a known deficiency in the environmental availability of that nutrient resource. Some supplements come in the form of whole foods and others look more like the supplements we are used to (e.g., capsules and tinctures). Supplements can be used to treat symptoms, and also to help restore and recover from injury.

If nutritional needs change over time then the best way of knowing what to consume is through someone's own body's intrinsic mechanisms, and not the conscious minds potentially biased overlay. Deviations from ancestral environments are likely responsible for many health problems in the early 21st century (i.e., eating outside of the context of the natural habitat for a species is likely to lead to dis-ease).

There are people who have a genetic disorder who may be fixed by (or the disorder is ameliorated by) a high dose of a vitamin that they could never get from food. That person's optimal diet is something from the range of ancestral diets, with the addition of supplements that they could never get from the food. It is artificial in a very particular way, and that artificial thing is what optimizes the diet for that person.

Humans ought to eat a species-appropriate (genetic appropriate) diet. The introduction of lower quality food leads to the generation of lower quality potential for people today, and for future generations. It is important for society to ensure the food selection is sending the right messages to the organisms genes and contains the right inputs for optimal functioning.

> **INSIGHT:** *It is easy to forget where food comes from when it only comes from the supermarket and from restaurants.*

3.6 Species appropriate, species specific diet

A.k.a., Ancestral diet, genetic appropriate diet, human ancestral needs for nutrition, human

> *ancestral nutritional needs for diet, species appropriate diet; i.e., we are here because of our ancestors.*

An optimal diet is deeply constrained by biology; it does not vary significantly in any environment. The first basic principle: You can be most healthy (or, only be healthy) on a diet that has been part of the normal diet of your ancestors for tens to hundreds of thousands of generations. What better indicator is there for what the optimal diet for humans could be than what humans evolved (adapted to) eating. There is a clear anthropological record showing that humans, hominids and pre-hominids ate meat in large quantities relative to glacial periods, giving them unique nutrients that allowed for changes to the body and brain. Approximately 99.9 percent of the human and pre-human experience was lived in a hunter gatherer context. Hence, most of the selection pressures that have sculpted and shaped the human genome are Pleistocene. Humans are still well adapted to that sort of environment and lifestyle. Modern life is radically discontinuous from everything that came before. Humans are not well adapted for the sedentary, indoor, socially isolated, artificial laden, sleep deprived, frenzied pace of modern life. And, the result is an epidemic of depressive and other illnesses. When it comes to human health and there is a lack of available knowledge, then the intelligent perspective should probably gravitate toward what the conditions for human ancient ancestors were. What were the conditions like over the millennia that we evolved. The important question is, "What did our ancestors do, and how can we best optimize our nutrition given what we know now?" It appears likely that the ancestors of modern humans were animal-based (a.k.a., animal-leaning, animal-centered) omnivores due to anthropological evidence and nitrogen-15 to nitrogen-14 isotope testing. (Schoeninger, 2014; Ben-Dor, 2019; Ben-Dor, 2021) Hence, not too far in the evolutionary past of humans, there is a deep evolved need for animal food (animal fat and meat). Evolutionarily, humans have been eating animals and using their materials nose to tail for hundreds of thousands of years. Hominids have been cooking meat and fish for at least 700,000 years. (Zohar, et al., 2022) Hominids have been using fire for at least 1 million years, though likely longer. (Berna, 2012)

> *Homo erectus [the evolved precursor to homo sapiens] was morphologically and behaviorally adapted to carnivory, was a social hunter of megafauna, ...[and] would have been a hypercarnivore with some 70% of the diet derived from animals. (Ben-Dor, 2021)*

In physics, there are base elements, and then, there are isotopes of the base elements. Elements with different atomic masses (a.k.a., weight) are called isotopes. The difference between a base element and an isotope of the base element is in the number of neutrons in the nucleus. In concern to stable isotope analysis, since C12 and C13 are stable, there has been virtually no change in the ratio between them over time. However, there are clear differences in the ratio of carbon in carbon containing substances. When a sample goes through the mass spectrometer it can determine the C13 to C12 ratio. That value is compared to a standard, and the difference between the sample and the standard is called the relative 13C content (a.k.a., delta 13 carbon, D13C, δ13C). Carbon-13 (13C) is measured in parts per thousand (‰). When analyzing samples, especially in the context of carbon dating or isotopic analysis, the ratio of the stable isotopes 13C to 12C is often expressed in per mil (‰) units. If a sample has a ratio lower than the expected or standard ratio by 5 parts per thousand, it implies a decrease in the concentration or ratio of 13C in comparison to the normal or expected ratio. This information is valuable in various studies, such as determining the sources of carbon in ecosystems, determining historical human diets, understanding past climate conditions, analyzing the age of organic materials using radiocarbon dating, and studying biochemical processes.

> **NOTE:** *C14 degrades and is not stable.*

Stable isotope analysis is a scientific way of describing the position on the food chain (i.e., trophic level) of different animals. Apex predators don't graze; they eat other animals primarily. Nitrogen and zinc isotope testing is used to find the tropic level of a species. Nitrogen-15 (15N) tells the carnivory story. Nitrogen isotope ratios increase with each trophic level. Plants contain a fairly constant N15. When herbivores eat plants they concentrate the N15 by approximately 3-5% in their collagen. Hence, if a collagen sample contains an N15 level greater by 5% than the local flora, the animal must be a herbivore; because it has been eating the local flora which it has concentrated.

Nitrogen-15 isotope testing of ancient human remain shows that humans have likely been eating predominantly animal products for most of their ancestry. The conclusion of Hedges (2007) is, "the ratio of animal derived protein to total protein (the dietary animal protein fraction) was typically more than 60% and sometimes up to 80% throughout prehistory. Of note, it appears likely that during the glacial periods on earth, the human diet was more animal-based (carnivorous), and during the interglacial periods it was typically a little less; because, of the higher prevalence of plant carbohydrate sources. Note that during the interglacial periods, the animals consumed were leaner, without as much fat on their bodies. Additionally, while this data differs from all current agrarian subsistence societies, it fits in with known pastoralist societies where milk is a major item of nutrition. (Hedges, 2007) Hence, for most of human existence, up to approximately 10,000 years ago humans were primarily animal eaters. The N-15 was found to be high in their bone tissue, which means, the source of protein for their collagen was coming from the consumption of high amounts of animal foods, and likely, ruminants in particular. Carbon isotope analyses (δ13C) of ancient humans shows that the carbon in the human bone tissue comes from C4 grasses. Hence, the ruminant animals being eaten were likely eating C4 grasses, leading to concentrations in humans also. When there is very low nitrogen 13 (N13), which is the nitrogen in plants, and high nitrogen 15 (N15) with high delta 13 carbon (D13C, δ13C), it indicates that what was eaten primarily had come from a ruminants that were eating grass. This science shows the predominant food that was consumed by our ancestors.

> **NOTES:** *C13 is found in higher quantities in marine mammals than terrestrial mammals. A higher C13 indicates a diet higher in seafood. Also, the common C3 plants are: wheat, rice, beans, and most fruit. The common C4 plants are: corn, sugarcane, and sorghum.*

There are two items of note when considering N15 testing. First, there is only nitrogen in protein and not in lipids. Fat consumption doesn't register on isotope studies. Secondly, nitrogen 15 isotope testing is a context relative test. Both the plants and the herbivores must be tested in the same area where the human remains were found, to see how high they are. If the environment has a lot of nitrogen in it, then it will be higher in the plants and herbivores than in other environments. Hence, in high nitrogen environments with plants that are high nitrogen, the herbivores that eat the plants will present nitrogen isotope samples close to carnivore. Hence, when a site is tested, the remains of all three (plants, herbivores, and humans) must be tested to see how high they are and to determine the trophic level of humans.

Ancestrally speaking, humans would have had opportunities to eat carbohydrates (from plants and Bees) and also, drink milk. And, they would have taken advantage of these opportunities (i.e., they would have eaten carbs, including fruit, tubers and processed grain, and drank raw milk and fermented dairy). It is important, however to pick the right carbohydrate sources, and/or process them to remove anti-nutrients.

Humans can live off of diverse sources of food; however, the useful question is: what is the most optimal diet for human beings? And, from the collected body of evidence (anthropological, archaeological, comparative anatomy, physiology, evolutionary biology, biochemistry, etc.) it is highly clear that humans are designed to sustain optimal nutrition from significant consumption of animal meat and fat sources, while retaining the ability to gather some (though not sufficient) nutrition from a diversity of other food sources.

There are also modern adaptations since 10,000 years ago, but these are relatively minor. However, an adaptation could be major for anyone eating outside of their ancestrally adapted diet. The genome has been shaped by an ancestral environment of hundreds of thousands of years with very minor changes. There are certain modifications (e.g., immunology and adult lactase persistence), but for the most part the basic biology is no different than that of human ancestors living 60 and more thousand years ago. Over the last 10,000 years, humans have been forced to consume more grains, because of their dwindling hunting grounds (in the case of indigenous hunter-gathers), and also, State subsidies on the production of grains.

> **NOTE:** *Where someone is on the planet likely influences their nutritional needs. In the northern and southern hemispheres, there is less light, more cold, and more fatty animals. Near the equator, there is less fat on animals, more sunlight, and more heat.*

What is known of current hunter-gatherers is that they crave meat and seek out meat. Cordain (et al., 2000) found that hunter-gatherers consumed high amounts (45-65% of energy) from animal food. Most (73%) of the worldwide hunter-gatherer societies derived >50% of their subsistence from animal foods, whereas only 14% of these societies derived >50% of their subsistence from gathered plant foods. This data shows that hunter-gatherers depend significantly on animal foods for their nutrition. (Cordain, et al., 2000) It is also important to point out that these figures would likely be higher in terms of animal food consumption if the wildlife animal stocks were more abundant and there wasn't such significant encroachment on hunting territory by settlements of modern civilization.

> **NOTE:** *Humans can be healthy on a lot of different diets, but there are specific foods and nutrients that they must have.*

The following essential nutritional components only come in significant quantities and bioavailable forms (i.e., appropriate qualities) from animal food, and include, but are not limited to (i.e., like all nutrients humans require, humans can be deficient in the following animal-only nutrients):

1. Animal peptides.
2. Anserine.
3. Biotine
4. Carnitine.
5. Carnosine.
6. Choline.
7. CoQ10.
8. Creatine.
9. DHA.
10. Heme iron.
11. Iodine.
12. Riboflavin (in significant amounts).
13. Saturated fat.
14. Taurine.
15. Vitamin A in a bio-available form (retinol plamatate from animal sources verses beta-carotene from plants).

16. Vitamin B12.
17. Vitamin B6.
18. Vitamin K2 (K2 in natto is from bacteria, not soybeans).
19. Zinc.

> **INSIGHT:** *There has never been an indigenous tribe discovered that does not eat meat.*

After meat/fish, the least toxic food plant sourced food (in the wild) is generally, fruit, then come the other parts of the plants. The fruit is generally less toxic because plants typically want mammals to eat it and disperse the seeds. The seeds are often the most protected/defended part of the plant. Plants, like most (if not all) organisms, don't want to be eaten, and in particular, plants don't want their seeds (the parts they use to reproduce themselves) to be digested (Read: killed). Plants cannot run away, so the way they defend themselves is through the production of toxins and thorns, and the protection of their seeds from digestion and assimilation by mammals. Further, plants are incomplete in required human essential proteins. Essential fats are not in the right form in plants. Vitamins and minerals, where they have them, they are not in the right form (e.g., carotene versus retinol, D2, and no, D3, etc.) and/or are bound to toxins that must be processed within the human body (e.g., oxalate). Provided a human eats enough fat and protein, the requirement for survival for carbohydrates from plants is zero; because of gluconeogenesis, which isn't to say that humans should not eat carbohydrates. It is also relevant to note here that the only source of significant fiber is carbohydrates.

As animals, humans are evolved to discern in a very sophisticated manner relative nutrient values of foods, through flavor and satiation, because that is what makes something good for the body, which gives the body the vigor and vitality to be resistant to disease and function at a high level.

> **INSIGHT:** *All hunter gatherers ate/eat meat and do not get chronic illness and do not have risk factors for cardiovascular disease as they age. (Raichlen et al., 2016)*

3.6.1 Diet and metabolic pathways

A.k.a., Metabolism types and diet.

Metabolism is intrinsically linked to the processes of eating and feeding, serving as the foundation for how organisms utilize the energy and nutrients obtained from food. Metabolism encompasses all the chemical reactions that occur within an organism to maintain life. These reactions are divided into two categories: catabolism (the breakdown of molecules to obtain energy) and anabolism (the synthesis of all compounds needed by the cells). Eating provides the materials and signaling for these metabolic processes. The macronutrients in food—carbohydrates, proteins, and fats—are broken down into their simpler forms (glucose, amino acids, and fatty acids, respectively) to be used as energy, or as building blocks for new compounds.

The digestive system breaks down the food we eat into nutrients, which are then absorbed into the bloodstream. These nutrients are transported to the cells, where metabolic processes transform them into energy and components necessary for the body's growth, repair, and maintenance. Without the intake of food, these metabolic processes would lack the substrates necessary to produce energy and sustain life.

> **CLARIFICATION:** *Metabolism is influenced by what is ingested, by the structure of the metabolic system itself, and by the composition and timing of meals. Different nutrients and different meal times having varying effects on metabolic pathways.*

Metabolism encompasses the complex biochemical processes that convert nutrients into energy and essential molecules, with metabolic pathways acting as the specific sequences of enzymatic reactions facilitating this conversion. The human body's capacity to sustain vital functions and promote repair is deeply rooted in the intricate workings of metabolic pathways. These pathways, driven by dietary intake, are the biological conduits that transform nutrients into energy and essential biomolecules. Human metabolism bifurcates into carbohydrate and non-carbohydrate pathways.

There are two known metabolic pathways in humans (which, used to be called the "fed and fasted" metabolic states):

1. **Carbohydrate metabolism** (provide energy and insufficient nutrients for complete repair): The central process in carbohydrate metabolism is glycolysis, which converts glucose into pyruvate, generating ATP (adenosine triphosphate), the cell's power unit (a.k.a., energy substrate). This serves as a vital source of energy, but offers limited substrates for comprehensive tissue repair.
2. **Non-carbohydate metabolism** (provide energy and nutrients sufficient for repair): Non-carbohydrate metabolism includes the metabolism of fats (lipid metabolism) and proteins (amino acid metabolism). These pathways are versatile, contributing to both energy production and the synthesis of new molecules necessary for cellular repair and growth. Fats and proteins also provide sufficient substrates for comprehensive tissue repair. A non-carbohydrate metabolism type is likely the primary metabolic state for humans, similar, to what a fasting state insulin looks like.
   A. **Lipid metabolism:** Fats are broken down into fatty acids and glycerol, which can be further oxidized to produce ATP. In periods of low

carbohydrate availability, fats become a primary energy source.

B. **Amino acid metabolism:** Proteins are broken down into amino acids, which can be used for producing energy, especially during prolonged fasting or intense exercise.

C. **The randle cycle (a.k.a., glucose-fatty acid cycle):** A biochemical mechanism (not really a cycle) that explains how the metabolism of glucose and fatty acids is reciprocally regulated. It outlines the mechanism that locks-out from the cell ("competition") between glucose and fatty acids for oxidative metabolism, affecting cellular energy production and utilization. It highlights how glucose and fatty acids interact with an oxidative metabolism within cells, influencing the production and utilization of cellular power/energy. This mechanism ("cycle") plays a critical role in maintaining energy homoeostasis but, when disregulated, can contribute to metabolic disturbances diseases, such as insulin resistance and type 2 diabetes. The randle cycle principle is the principle of cellular energy/power unit lockout and the damage this will cause to intracellular and cellular materials. When cells lock-out carbohydrates, there is likely to occur a set of dis-eases:

1. **Insulin resistance:** When fatty acids predominate as the energy source, glucose uptake by cells is inhibited, contributing to higher blood glucose levels and decreased insulin sensitivity.
2. **Lifestyle diabetes:** Chronic disregulation of this balance can lead to type 2 diabetes, characterized by high blood sugar, insulin resistance, and beta-cell dysfunction.
3. **Glycation of tissues (advanced glycation end products, AGEs):** When glucose is consistently locked out of cells due to a high carbohydrate load in a diet containing mixed macronutrients. Glycation refers to the binding of glucose to proteins without the action of enzymes, leading to the formation of harmful compounds known as advanced glycation end products (AGEs). AGEs can damage tissues, contributing to the complications associated with metabolic diseases, including vascular damage, inflammation, and increased oxidative stress.

3.6.2 Diet and blood-types

The dietary needs of animals are specific to their species and hinge on their unique evolutionary adaptations, physiological requirements, and ecological functions, rather than their blood type. This stands in contrast to certain human dietary theories that propose a person's blood type as a factor influencing their nutritional needs. In reality, an animal's diet is influenced by the anatomical and metabolic changes it has undergone to adapt to its environment and the availability of food within that environment. Within the animal kingdom, variations in blood type exist, but these differences do not dictate dietary preferences or nutritional requirements. Instead, diet is primarily a function of species-specific traits and ecological niches, ensuring that animals consume the nutrients necessary for their survival, reproduction, and overall health. This distinction highlights the complexity of nutritional ecology and the importance of understanding diet through the lens of species-specific adaptations and ecological context.

3.6.3 Intergenerational survival and diet

A species cannot live intergenerationally (from generation to generation) if they are missing essential nutrients from their diet. Pottenger's cat study, conducted from 1932 to 1942, serves as a seminal investigation into the impact of diet on long-term health across generations. The research revealed that a deficiency in essential nutrients could lead to a cascade of health issues over successive generations. It was observed that cats fed a diet lacking in crucial nutrients, particularly raw animal proteins and fats, developed various health problems and experienced a decline in reproductive capabilities. These issues became more pronounced with each subsequent generation, indicating that without the necessary nutritional components, a species may suffer from degenerative health conditions, ultimately compromising its ability to thrive intergenerationally. This study underscores the foundational principle that access to a complete and nutrient-rich diet is vital for the ongoing health and continuity of a species. (Emlet, 2013)

3.7 Food and age-dependent adaptation

The studies show that young people with an agricultural ancestry can do OK on an organic meat and annual plant agriculture diet. However, humans have spent more than 1 million years as hunter gatherers, and that is the permanent residue of adaptation that is there for every human once they are between 30-50 years of age, particularly over 50. Note that this adaptation is not just for diet, it for a light and dark (and other needs also). Nobody is adapted to an ultra-processed food diet. Also, the early 21st century ultra processed diet is toxic to everyone and sets everyone up for a lifetime of lesser thriving, food addictions and disease. Everyone does best on a hunter-gatherer diet, some (because of thousands of years of agriculture) can tolerate (and not get sick) from agricultural foods under 50. (Rutledge, et al., 2020)

Effectively, the age-dependent adaptation principles is:

- Everybody up until the age of 30 should not eat anything someone after the agricultural revolution, but before the 1920's would not have eaten (i.e., do not eat ultra-processed foods). Then, between 30 to 50 years of age an onward, have a strict ancestral in diet, and consume a diet back before the agricultural revolution, back 20-30,000 years, which is a diet encoded into the genome through hundreds of thousands of years. If this is done, then lifestyle (Read: non-genetics based, phenotype) diseases will be most unlikely to arise, and cells will stop aging around 70 years of age. (Rutledge, et al., 2020)

3.8 Human protein requirements

People who eat food poor in essential amino acids will have to eat more to achieve nutritional sufficiency. Every day, each human needs a certain number of grams of digestible, [in]dispensable, essential amino acids. So, if someone eats a high-quality protein, then they can eat less. If someone eats a low quality protein, the only way to achieve sufficiency is to eat more, which means they will have to get (their body will drive them to consume) more calories into the body. Humans do not over eat on a nutritionally sufficient, species appropriate diet; their bodies will not allow them. When a human is complete, the signal to continue feeding the body ceases. However, if the body doesn't get enough of the macro-nutrients, it will continuously be hungry, consuming more calories than needed in order to meet its need for protein.

Animal proteins, like those found in meat, dairy, and eggs, are considered complete proteins as they contain all essential amino acids in adequate proportions required by the human body. Plant proteins, on the other hand, may lack or have lower amounts of one or more essential amino acids. Some plant proteins, like those from soy, quinoa, and buckwheat, are considered "complete" proteins, in that they contain all essential amino acids. Here, "complete" is in quotes, because although these plants have all amino acids, they are not actually complete protein sources for humans. While these plant sources indeed possess each of the amino acids, they do not align with the specific ratios or quantities of complete proteins as required by human physiology. Animal proteins are considerably easier for humans to digest and have higher bioavailability than plant proteins. Additionally, these "complete" protein plant sources contain components that hinder the absorption of certain nutrients or have lower digestibility due to the presence of anti-nutrients like phytates and fiber. These "complete" plant sources of amino acids also carry with them a variety of other molecules that can harm human digestive physiology and hormone balances, such as saponins, glutens, lectins, and various phytochemicals (phytosterols that resemble human sterols and phytoestrogens that mimic human estrogens, both of which can interfere with proper human-body signaling).

Here, it is best to talk about digestible amino acid requirements rather than protein requirements or even, just amino acid requirement; because what is required is digestible amino acids. Each indispensable amino acid is a nutriment that humans have a requirement for (in general, daily). There are several ways of measuring protein digestibility, the two most common are the DIAAS (newer and more accurate for human purposes) and the PDCAAS (older and less accurate for human purposes):

1. Digestible indispensable amino acid score (DIAAS): A newer method that focuses solely on the digestibility of indispensable amino acids (those that the body cannot synthesize on its own) and their ability to meet human requirements.
   A. Uses pig ileal digestibility; actually sees how much was utilized between the mouth and the ileum without any contamination in the large intestines or secum.
   B. DIAAS scores can exceed 1, indicating higher protein quality.
   C. Looks at individual amino acids.
2. Protein digestibility corrected amino acid score (PDCASS): An older method of measuring protein quality based on both amino acid requirements and digestibility.
   A. Overestimates protein quality from plant source foods.
   B. Underestimates protein quality from animal sourced foods by truncating those animal source foods at 100, because, PDCAAS does not include the combining for foods. In other words, PDCAAS scores range from 0 to 1, with 1 being the highest quality.
   C. Uses rate fecal digestibility.
   D. Doesn't look at individual amino acids.
   E. One scoring pattern.

3.9 Food as energy

Food provides the body with the necessary nutrients that are converted into energy through the process of metabolism. The body's ability to function and perform activities relies on the energy obtained from the food we consume. The balance between energy intake (food consumption) and energy expenditure (physical activity and metabolic processes) plays a critical role in maintaining overall health and well-being.

Taking into account the body's energy needs, three distinct types of energy expenditure become essential:

1. **Basal metabolism (a.k.a., resting energy rate expenditure, REE; resting metabolic rate,**

RMR; cellular and metabolic process energy expenditure) - refers to the typical amount of energy expended by an individual at rest to maintain vital bodily functions such as breathing, circulation, cell production, and maintenance of body temperature. What energy does the body need to do regardless of what is done by someone on top of that), such as maintain bone density, rejuvenate muscles, keep organs going, etc? It represents the energy required for the body to function while at complete rest, both awake and in a fasting state, under controlled environmental conditions (typically measured in the morning after a full night's sleep and 12 hours of fasting). Basal metabolic rate (BMR) accounts for the largest portion of daily energy expenditure, typically around 60-70% of total daily energy expenditure, and varies among individuals based on factors such as age, gender, weight, body composition, and genetics.
   A. The basal metabolic requirements are completed/performed by fat and protein; carbohydrates are not needed for this, but if they are consumed, then carbohydrates can do some of the basal metabolic functions. The protein and fat nutrients for basal metabolism are found in some combination of animal sources: land mammals (preferably, fatty meats), eggs, full-fat dairy, seafood (preferably, oily fish).
2. **Standard energy expenditure (a.k.a., baseline lifestyle energy expenditure, baseline physical movement energy expenditure)** - refers to standard energy expenditure refers to the total daily energy expenditure beyond the basal metabolic rate, including physical activities such as walking, household chores, occupation-related activities, and other typical non-extreme exertion types of movement or activities throughout the day. SEE includes all activities except those related to resting metabolic requirements and extreme physical motions.
   A. For energy expenditure (beyond basal), the body looks to fat and carbohydrates. Again, carbohydrates are not needed, but if carbohydrates are present then the body will use it as fuel, first.
3. **Over-standard energy expenditure (a.k.a., intense physical energy expenditure, physical exercise energy expenditure)** - refers to an additional energy expenditure above the standard energy expenditure level. It represents the surplus energy expended during intense physical activity, exercise, or any activities beyond the regular daily physical activities that contribute to standard energy expenditure.

Given the three types of energy expenditure, humans have energy intake requirements for specific macro-nutrients:

1. A typical female adult needs at a minimum, approximately, 2000 calories a day, with normal daily activity, not including extreme activity.
   A. Basal metabolic energy Kcal intake requirements:
      1. 1500 Kcal for the average female basal metabolic requirements. 1500 Kcal is needed for body repair and basal continued functioning. A total sedentary woman needs a minimum of about 1500 calories of food energy per day in order to survive (plus small, but essential, amounts of micronutrients and minerals).This must come predominantly from fat and protein.
   B. Standard energy expenditure energy Kcal intake requirements:
      1. 500 calories on top of the 1500 for someone who is just generally active. 500 Kcal needed for extra energy expenditure. This must come from either fat or carbohydrates.
   C. Hence, for the average woman, as a starting point, and where calories are cared about, then eat 1500 calories a day of protein and fat as a minimum, in the form that the body [ancestrally] wants them. Then, if s/he does not need to lose weight, then add another 500 calories, mostly of fat, but carbohydrates may (or may not) be OK also, as long as the Randle cycle (a.k.a., glucose-fatty acid cycle, metabolic energy substrate interplay cycle) isn't significantly triggered.
2. A typical male adult needs at a minimum, approximately, 3000 calories a day, with normal daily activity, not including extreme activity.
   A. Basal metabolic energy Kcal intake requirements:
      1. 2250 Kcal for the average male basal metabolic requirements. 2250 Kcal is needed for body repair and basal continued functioning. This must come predominantly from fat and protein.
   B. Standard energy expenditure energy Kcal intake requirements:
      1. 750 calories on top of the 2250 for someone who is just generally active. 750 Kcal needed for extra energy expenditure. This must come from either fat or carbohydrates.
   C. Hence, for the average man, as a starting

point, and where calories are cared about, then eat 2250 calories a day of protein and fat as a minimum, in the form that the body [ancestrally] wants them. Then, if s/he does not need to lose weight, then add another 750 calories, mostly of fat, but carbohydrates may (or may not) be OK also, as long as the Randle cycle (a.k.a., glucose-fatty acid cycle, metabolic energy substrate interplay cycle) isn't significantly triggered.

NOTE: *Please note that the above caloric values are approximate and can vary based on individual factors such as activity level, health conditions, and specific dietary needs.*

The first observation from this information is that fat is the ubiquitous macro-nutrient; fat can be used for the most processes the body needs to run. Fat consumption has no impact on glucose and also will not significantly impact insulin (if the fats are naturally biocompatible with the human organism).

To convert calories per day to joules, the following equation is performed:

2 Kcal of energy • 4.2 KJ of energy = ~8368 KJ (~8.4MJ) per day

- Wherein,
  - 1 calorie = 4.184 joules

NOTE: *Most humans only have about 4 grams of sugar in their blood at any time. And, it is the body's job to make sure the body stays at that level of sugar in the blood. To put this in perspective, on average, a medium-sized banana (approximately 7 to 8 inches in length) contains about 14-15 grams of sugar.*

3.10 Food preparation

There a several different categories of food for humans. Some foods, particularly those in the categories of plants and fungi, need to processed correctly using technology in order to transform them into their safest and most usable/nourishing form. Food preparation can be key to nutritional acquisition and the removal of harmful chemicals. Humans are an animal-leaning omnivore and through various technologies they are able to render a lot of foods that would otherwise be inedible on the wild landscape, edible. Food processing technologies include both mechanical technologies and chemical technologies. Most wild plant food has to be processed for someone prior to consumption. Berries and other fruits not so much, but for most staple foods there is a process that must be gone through to render them edible. And, that is one of the unique things about the human animal. Humans can take foods that are otherwise inedible to them, and through external technologies they have developed (e.g., mechanical or chemical technologies), they are able to render a lot of material (food) edible, and in some cases, more nutritious. Hence, humanity is not just an omnivore, but a technological omnivore. Not highly complex technologies like smart phones and 3d printers, but basic technologies like grinding and cooking that humanity has had for millennia. These technologies allow humanity to prepare and consume foods that might otherwise be too tough, unpalatable, or have chemicals in them that need to be deactivated through heating and/or rinsing for them to be safely digested.

Some foods found in the environment must be prepared first before they become foods safe to consume. Traditional cultures prepared foods in a variety of ways to make them less toxic (inflammatory; or, side-effect causing). For example,

1. Tomatoes are peeled and de-seeded.
2. Beans are soaked multiple times and then boiled (or, pressure boiled), and then, the water is disposed of.
3. Potatoes are peeled, and then boiled (and the water is disposed of), before they are fried in fat.
4. Acorns are washed and cooked multiple times.
5. Cabbage is fermented for long periods of time.

3.11 Human optimization through food

NOTE: *When we do the right things with and to our bodies to support the biophysiology, then it recovers rapidly and is most likely to expresses optimal functioning.*

There are two general principles for eating food to optimize human functioning:

1. Don’t eat the foods that make you weak.
2. There are foods that are just about good for everyone:
   A. There are foods for building proteins and physical structure - mostly animal proteins and animal fats. Animal foods are good for just about everyone, providing high quality protein and fats. Pasture animal foods are most nutrient dense for humans. Nutrient density is the amount of bioavailable complete proteins, fats, micronutrients, vitamins and minerals.
   B. There are foods for energy - primarily from lipids (preferably animal), carbohydrates, and proteins through gluconeogenesis (during famine-like conditions).
   C. There are food for [trace] minerals (mineral supplements) - salt, and mineralized animals and herbs/spice).
3. There are medicinal foods (supplements) - derived

from plants mostly known as herbs that alter physiology in was that improve the current state of health and/or alter psychophysiology.

INSIGHT: *We evolved to eat food. Supplements are either a crisis management or biohacking optimization strategy.*

When people don't eat well, and in particular, when they eat nutrient deficient food, they may develop an eating compulsion, and feel the need to eat more often than they would otherwise need to, and feel the need to eat food that is more entertainment than actual nutrition.

3.12 Food and dis-ease

A.k.a., Evolutionary matching and mis-matching, diseases of evolutionary mis-match, diet and disease, neolithic and early 21st century diseases, diseases of modernity.

The introduction of species inappropriate foods likely compromises the immune system and makes people more susceptible to pathogens and inflammation. In many cases of disease, there are biochemical drivers for disease. If those biochemical drivers are removed by a change to the diet and lifestyle, while addressing underlying pathologies, then even if someone has a genetic susceptibility for the disease, the likelihood of getting the disease is decreased. Such behavior is not restrictive; it is intentional, and that intention is positive. Because if someone is cutting out foods or combinations of foods that are triggering inflammation, then that person might be getting to the root cause of disease. When someone can think clearly, then they are going to make better decisions. Some diets induce inflammation and brain fog in people, lowering their potential and causing them to make poorer decisions. The mismatch between human biology, genes, diet, and lifestyle is driving the current epidemic of diseases in the early 2st century. There is always an explanation, a reason, for disease. Maybe investigators don't find it, but it is there.

INSIGHT: *No animal on the planet eating its natural diet gets tooth decay.*

Sometimes diseases are confused with toxicities. The over consumption of refined sugar, for example will lead to hypoglycemia, and then, diabetes, but in this case the "disease" is really a toxicity caused by too much sugar in the blood (which is toxic) over too long a period of time. The toxicity manifests as type 2 diabetes.

When animals in zoos are fed diets similar to modern human foods, they begin to exhibit conditions traditionally considered human diseases. Simply, animals in zoos that get fed modern food get modern [human] diseases. This observation suggests that such diseases are not exclusively human, but can also affect non-human animals if they consume the same types of food. Therefore, the link between diet and disease appears to be a crucial factor, indicating that the food itself may be a primary cause of these conditions, rather than the diseases being inherently human-specific. What is a human disease if animals will get them too if fed the same food that humans eat. If non-human animals eat modern human food they get modern [human] diseases.

3.12.1 Human predisposition

Human beings are all genetically predisposed to have an ideal weight. The only difference between individuals is their propensity or ability to get away with self-abuse. Sometimes humans don't even know they are abusing their bodies when they consume specific substances.
There can be generational declines in health when the diet for the genetics isn't fulfilled (over generations).

3.12.2 Syndromes

INSIGHT: *Food compulsion isn't a character disorder, it is a chemical disorder. Mixing the wrong nutrients in the body (e.g., randle cycle activation) will disrupt hormones and microbiomes, and create food-drives that are disordered (e.g., overeating in the case of mixing carbohydrates and fat).*

A syndrome is a result of not living aligned with ancestral biophysiology and/or a healthy psychological environment. Medical institutions are constantly coming up with new names for new syndromes that in reality involve a complex of systems from electro-chemical, biological, psychological, and lifestyle factors that lead an organism out of alignment with its expected biophysiology, and thus, experience dis-ease symptoms that are given institutionally treatable names.

If you eat the way the body is designed to eat, the body will work the way out it is designed to work, and if you don't, it won't. What are the bodies of our species designed to eat? The evolutionary principle is:

What you have been adapting to the longest is what you are designed for.

Humans have been apex predators for over 2 million years. The definition of an apex predator is an animal-based (carnivore) organism. Apex predators eat other animals, primarily. Humans have been adapting to mostly animal foods for millions of years. To sustain optimal health, humans should eat foods that they are well adapted to eat, particularly after middle age.

3.12.3 Food as entertainment

Entertainment foods displaces real nutrition in the diet. Many people in the early 21st century use food to meet unmet non-nutritional needs in their lives. They overstimulate their senses with continuous/ regular feedings of hyperpallatable, highly-processed "foods". This relationship is easily seen when food is used as "entertainment" (unnecessary excessive/ regular consumption); which, may or may not be with entertainment (i.e., in a healthy social gathering). When a surrounding environment lacks conditions for complete fulfillment, and entertaining food is available (as a condition), then food might turn into entertainment. Instead of consuming food for its intrinsic nutritional value to the organism, humans consume food because of flavor, propaganda, and/or business brand. When uplifting social and environmental connections are not present in an individual's set of life relationships, then food is more likely to be used as entertainment (distraction from the pain of incomplete fulfillment).

3.13 Over-eating (over-consuming food)

> **NOTE:** *Under environmental conditions of scarcity, there is an urge to eat whatever is available -- those desperate enough will eat whatever is available.*

There is a difference between eating to fullness (i.e., to taste and to completness), and eating to a point where you body physically tells you to stop stuffing it with more food (i.e., eating until you feel stuffed and you potentially want to vomit). Never do the latter. Just eat real food when it tastes good, until it stops tasting good. There are things that taste good and are not good for you (as in, highly palatable and ultra processed foods). A good first principle to stop overeating is, just eat fatty meat until it stops tasting good. When each meal is fulfilling, there isn't that neverending hunger to not stop eating. And, after overeating on hyperpallatable foods for decades, often, one has to relearn one's own hunger signals, by just eat fatty meat until it stops tasting good, which is what actual satiation for a human is.

Certain medications and specific food groups, such as dairy and carbohydrates, have the potential to alter normal hunger signals. In the absence of medications or dietary substances that interfere with hunger cues, then just eat fatty meat until it stops tasting good. In other words, without the influence of medications and food groups that disrupt hunger perceptions, individuals are advised to consume fatty meat until the palatability diminishes. Outside of these special circumstances though, everyone should be able to just listen to their body and have their body tell them when to stop it eating. Therein, should someone feel a need to eat more frequently than once daily, one should feel free to do so.

The body knows when to stop eating; because, it is getting the right signals; which, only works if the body ("you") are eating what the body ("you") are designed to eat. There are some foods that can interfere ("mess") with humans' nominal hunger signals. For instance, there are natural opiates in some dairy (particularly milk), which can give more of a compulsion to eat than just hunger. Carbohydrates, as a food group (especially when mixed with fat and salt), can do this as well.

> **INSIGHT:** *Just eat fatty meat until it stops tasting good, and let your body tell you when that is. And, do that as many times during the day as tastes good to "you" to meet "your" biological demands. Then, drink water an hour or two outside of that. Drinking water during a meal can dilute the stomach's hydrochloric acid, and reduce the efficiency of digestion.*

If "you" can't stop eating just going by taste, then reconsider what is being eaten; there may be any of the following, including but not necessary limited to:

1. A non-species specific diet.
2. Long-term nutritional deficiencies.
3. The presence of hyperpallatable foods.
4. The presence of ultra-processed foods.
5. The wrong combination of macronutrients in a meal.
6. A fungal overgrowth or other micro-biome infection in the digestive system.
7. A low fat meal (note that people will eat more, up to twice as much, if they eat low fat -- low fat will cause less satiation).
8. Too little protein (note that people will persistently graze to acquire sufficient protein if there is not sufficient protein, to replace protein turnover, in most meals).
9. Too much salt.

People are only going to eat too much:

1. If they are exposed to hyperpalatable foods. In the early 21st century, ultra-processed foods are designed and sold to be addictive. Business profits off of food addiction, and secondarily off of medical care. Food is advertised, and ultra-processed foods (a.k.a., fast foods) are a large part of the culture, if not sometimes imposed by the culture. In fact early 21st century society encourages people to become food addicts.
2. If their cells are starving and/or their hunger drive is not being satisfied by the food-like substance that they are putting into their bodies; either, because the food doesn't contain the required nutrition or the Randle cycle is locking those nutrients out of the mitochondria (causing starvation).

Human bodies regulate hunger normally when not exposed to hyperpalatable (artificially enhanced) food. In the case of hyperpalatable food, bodies are naturally drawn to eat more than the body needs (to meet the "bliss point"). In the case of artificially flavored foods, their consumption confuses the body's ability to identify what foods to eat, and how much to eat.

> **QUESTIONS:** *What causes us to eat in a way that damages our health? What happens when you can have any flavor almost whenever you*

want?

Almost everyone who overeats (Read: over-consumes food/food-like substances), overeats because of at least one of the following because of:

1. **Macronutrient insufficiency** - insufficient amino acid (protein) consumption so there not satiation.
   A. This is eliminated by eating a primarily animal-based diet, where sufficient protein and fat are consumed together.
2. **Micronutrient insufficiency** - insufficient micronutrient consumption so there is not satiation. Fundamentally, there is no such thing as moderation when it comes to eating empty (i.e., nutrient deficient) calories.
   A. This is eliminated by high quality, nutrient dense, bio-available foods (ensuring nutrient bio-availability) and not consuming anti-nutrients.
3. **Hyperpalatability and biomolecular manipulation** - flavoring (aroma) added and texture designed "food" to trick the brain into liking it and wanting more; hyperpalatable foods can make people over-consume. Stimulating specific neurons can drive overeating. For example, cannabanoids impacting the CB2 receptor and stimulates hunger.
   A. This is eliminated by not adding neuro-stimulants (e.g., MSG, cannabinoids, etc.) and flavoring to food. Eliminate things that look like food, but are not.
4. **Meal diversity (foods combining)** - people who eat many different types of food in a sitting are likely to eat more, because the switching from one food to the other partially interrupts completeness signals. In other words, the greater the number of unique foods in a meal the more food you are likely to eat.
   A. This is eliminated by eating simple nourishing meals.
5. **Starch and fat combining** - predisposed people who mix starches and fat are likely to eat more per meal. By adding salt and/or sugar to a combination of starches and fat, over-consumption becomes increasingly likely. The most simple example of this is oil fried french fries.
   A. This is eliminated by not making meals composed primarily of starches and fat that people know they are predisposed to overeat.
6. **Pathogens** - that live in the human body, interact with it biochemically, and produce neuro-psychological drives. Candida is a well-known fungi that can populate in the intestines and drive simple sugar seeking behavior.
   A. This is eliminated by eating a species appropriate diet, and possibly, the selective use anti-pathogenic compounds.

Generally, when someone gets the biochemistry of food right, then everything else falls into place - the cravings disappear; because, s/he is nutritionally sufficient, no longer has a digestive microbiome infection, has fixed his/her metabolism, optimized his/her hormones, optimized his/her digestion, and feels good.

> **NOTE:** *It is relevant to note here that the idea that, "More food = more energy", is incorrect. What is correct is that more food past threshold = less energy. If you don't meet, or you exceed, critical nutrients, then there will exist a lessening or worsening of function.*

3.13.1 Food cravings and food addictions

A.k.a., Appetite and satiety.

The human body craves naturally, because it needs something more to feel complete. The body can also be induced to crave in response to specific external stimuli (Read: stimulating bio-molecules), such as opiates. When humans eat evolutionary compatible foods, their cravings become signals to the body to acquire the building blocks they are missing. And yet, a body can be made to crave things to its own detriment. Addiction is any behavior associated with craving, temporary relief, negative consequences, and a lack of control. If someone has a craving for something naturally craved by the body, then s/he is responding to his/her environment with an appetite for a nutrient. Someone's appetite for a specific nutrient has been calibrated to that body's requirements for that nutrient, and that specific nutritional response causes that body to seek out foods that will redress the shortfall of that specific nutrient. This concept revolves around the body's innate ability to regulate its nutritional needs (through palatability and felt satiation on the consumption side, and food seeking behavior on the acquisition site), wherein an individual's craving for (Read: drive to acquire) a specific nutrient aligns with his/her physiological requirement for that nutrient. This specific nutritional response prompts the body to seek out foods rich in the needed nutrient to address the deficit. This is a very important means that all humans and all other animals have in ensuring that the body is complete in material inputs.

> **INSIGHT:** *Everyone should question the suggestions by industries and States when they tell you that the majority of your diet should be made up of crops that are heavily subsidized by the State. The government needs the population to eat massive amounts of subsidized corn, wheat, and soy, so it can get its investment back.*

There is a second dimension to cravings -- the microorganisms connected with the digestive system of an organism itself can induce food seeking (craving) behavior in that organism (i.e., they can control/ influence a human's behavior through a complex of bio-molecules). The digestive microbiota (microbiome) can induce unhealthy cravings in humans if it becomes over-populated by specific species (e.g., candida fungi inducing simple carbohydrate cravings). Of note, microbiota have a common language, one within their own species, for quorum sensing, well as, a universal language that they use to communicate between species.

Satiety is the concept for the complex bio-molecular process of feeling complete and losing the drive to eat more. Satiety, conceptually speaking, is what causes someone to stop eating (i.e., to terminate a meal when food is still present). The brain determines hunger and satiety in response to signals it receives from inside (e.g., nutrient levels) and also outside (e.g., food odors) the body. These signals are processed in the brain and drive the organism to eat, continue eating, and stop eating. In other words, all of this information is integrated by the brain, which uses it to generate the overall feeling/ drive of hunger or satiety. (Guyenet, 2017) When seeking to stop cravings for knowingly harmful foods, early on in the process, it is important to control the food environment so those outside environmental cues to eat food-like substances (e.g., highly processed foods) are not present.

> **INSIGHT:** *The body chases nutrients it doesn't chase calories.*

A craving is the responding of an appetite. In concern to a human's desire for food, their "appetite", there are three basic principles when it comes to appetite:

1. Appetites are a biologically evolved mechanisms for redressing nutrient balance.
   A. Appetites can become "confused" when artificial flavors and highly processed (non-biologically evolved foods) are introduced into the diet. Just like pheromones help someone pick a genetically appropriate mate, flavor helps someone pick a nutritionally appropriate meal.
2. The primary appetite is for protein.
   A. If there is insufficient protein consumed, the human will likely continue to eat.
3. If someone has a food craving, it because of what s/he has eaten and/or because of something s/he is missing.
   A. Some modern foods, particularly hyper-palatable foods, cause aberrant food cravings for food-like substances.

Highly processed food cannot be eaten in moderation. If "you" ever finds "yourself overeating any processed for "you" have to stop eating processed food altogether. In place of any highly processed food, choose real foods for their flavor in combination with nutrients they provide. Anyone can no more have processed food in moderation than an alcoholic can have alcohol in moderation. After stopping processed food, the more even "you" can keep "your" blood glucose, the easier "you" will find it to control "your" eating. One of the best tips to control "your" eating is to wear a continuous blood glucose monitor and use its data to control "your" blood glucose level. If blood glucose dips below normal, and s/he is not fat adapted, then the body will try and get that person to eat some fast carbohydrates (as that is what you are used to fueling on). If the body was fat adapted, when blood glucose dips below normal, then that is the time the body would naturally call upon body fat or triglycerides in the blood stream to put energy back into the blood stream. Secondly, eat no more than three times a day and never snack (i.e., eat a maximum of three times a day). The moment food enters the mouth, a whole complex biomolecular process starts to take place.

Food manufactures fully realize that it is possible to create addictive foods and foods that one started eating, cannot be stopped. Addiction is profitable. If someone can sell a buyer something, and the buyer like it, but does not need to buy it again, then the seller does not maximize the lifetime revenue of the buyer as a customer in the same way as if the seller sells something and the buyer becomes addicted to it. Hence, the natural impetus of business is to vector in the direction of addiction, and the businesses that do vector in that direction do better than those that don't (i.e., they compete better for market share).

> **INSIGHT:** *Always question the motives; who gains when the public is told by an authority to eat a particular food item or group, rather than another food item or group? Who gains when the State creates a food pyramid guide that informs the public that the guidelines are to eat mostly carbohydrates (plants)? If the guidelines where to inform the public that they ought to eat mostly animal foods?*

Hyper-palatable foods can create food addiction and are commercial products designed to trigger over-consumption and re-consumption (i.e., re-purchase). This is what most food chemists do for their profession. They use knowledge of physiology, biochemistry, and food flavoring to create uniquely palatable combinations of things that they know are going to sell well. Food scientists artificially induce cravings through their manufactured food-like creations. Many food scientists follow a formulaic approach toward manipulating and exaggerating food-seeking desires. Food scientists use a variety of techniques to get consumers to continue to eat their products, including, but not limited to, a mixture of flavors, textures, and reward and satiety manipulating chemicals.

Food scientists have taken advantage of evolutionary traps in humans to get consumers to purchase and