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In-Situ Nutrient Recycling and Management

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Abstract

One of the most important process occurring in the ecosystem is nutrient recycling, which describes the use, movement and recycling of nutrients in the environment involving both living and non-living components using biological, chemical and geological process. For economic and environmental reasons, it is essential that nutrient cycling is used more efficiently in the farm. To achieve this goal, reduction in long-distance nutrient flows, as well as promoting true on-farm recycling is required in which nutrients return in the form of crop residue or manure to the fields from which they came. There are a number of strategies to help farmers reach the goal of better nutrient cycling. However, there are potentially large flows of nutrients onto and off of farms. The inflow occurs as commercial and organic fertilizers and amendments as well as animal feeds are imported onto the farm and in manures and composts brought from off the farm. Exports are mainly in the form of crops and animal products. In general, larger amounts of nutrients are exported off the farm in vegetation (grains, forages, vegetables, etc.) than in animal products. Nutrient flows are of great concern because as nutrient levels decline, the soil rapidly degrades. Nutrient recycling can be done by effective utilization of straw, weed and other biomass, crop residues. Even fallow period can help nutrient recycling as well as maintenance of soil fertility. Crops producing more biomass if utilized well are more beneficial for effective nutrient recycling.

1. Introduction

A nutrient cycle (or ecological recycling) is the movement and exchange of organic and inorganic matter back into the production of matter. Flow of Energy is a non-directional and noncyclic, whereas the movement of mineral nutrients is cyclic. Mineral cycles include the carbon cycle, sulfur cycle, nitrogen cycle, water cycle, phosphorus cycle, oxygen cycle, among others that continually recycle along with other mineral nutrients into productive ecological nutrition.

The nutrient cycle is natural recycling process. All forms of recycling have feedback loops that use energy in the process of putting material resources back into use. Recycling in ecology is regulated to a large extent during the process of decomposition. Ecosystems employ biodiversity in the food webs that recycle natural materials, such as mineral nutrients, which includes water. Recycling in natural systems is one of the many ecosystem services that sustain and contribute to the well-being of human societies.

Changes in nutrient cycling can indicate changes in ecosystem function. Nutrient cycling cannot be measured directly but calculated from a quantitative network of nutrient cycling. Nutrient cycling can be calculated using a variety of methods, (Fath and Halnes, 2007; Latham Ii, 2006; Fath and Patten, 1999; Allesina and Ulanowicz, 2004; Vanni, 2002), with Finn's Cycling Index (Finn, 1976) being most common. Nutrient cycling can indicate changes in productivity and consumption; it can influence food web resilience and resistance, though to date has not been well-linked to robustness - which is more dependent on link distribution (Schaeffer *et al*., 1988; Canning and Death, 2017; Zhao *et al*., 2017; Mougi and Kondoh, 2016; Saint-Béat *et al*., 2015).

Rajkhowa D. J. and Borah D. (2008) informed that rice straw incorporation increased the organic C in the soil by 2-11 % compared with straw removal. It also increased the microbial population in soil substantially irrespective of the decomposer used. Inoculation with CDM led to build-up of microbial population in the soil. Thus, rice straw incorporation with cellulose decomposing micro-organisms and earthworms resulted in higher yield, increased nutrient uptake, improved residual soil fertility and soil microorganism status and ultimately higher benefit: cost ratio of wheat.

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2. Why Nutrient Recycling is Important?

2.1 Transformation of matter from one form to another

Nutrient cycles allow the transformation of matter to different specific forms that enables the utilization of that element in different organisms. Therefore, nutrient cycles enable the provision of elements to organisms in forms that are usable to them.

2.2 Transfer of elements from one location to another

Nutrient cycles allow the transfer of elements from one location to another. Some elements are highly concentrated that are inaccessible to most living organisms, such as nitrogen in the atmosphere. Nutrient cycles allow these elements to be transferred to more accessible locations such as the soil (for the case of nitrogen).

2.3 Functioning of ecosystems

Nutrient cycles assist the functioning of ecosystems (which humans are part of). The ecosystem which requires the state of equilibrium to function properly, restore to the equilibrium state through the nutrient cycles.

2.4 Storage of elements

Nutrient cycles facilitate the storage of elements. Elements that are carried through the nutrient cycles are stored in their natural reservoirs and are released to organisms in small amounts that are consumable. For example, through the nitrogen cycle, plants are able to use nitrogen in small suitable amounts even though it is abundant in the atmosphere.

2.5 Link organisms, both living and non-living

Nutrient cycles link living organisms with living organisms, non-living organisms and non-living organisms with non-living organisms. This is essential because all organisms depend on one another and is vital for the survival of living organisms. These organisms are linked by the flow of nutrients which is designed by the nutrient cycles.

2.6 Regulate the flow of substances

Nutrient cycles regulate the flow of substances. As the nutrient cycles pass through different spheres [biosphere, lithosphere, atmosphere and hydrosphere], the flow of elements is regulated as each sphere has a particular medium and rate at which the flow of elements is determined by the viscosity and density of the medium. Therefore, the elements in the nutrient cycles flow at different rates within the cycle and this regulates the flow of elements in those cycles.

3. Improving Nutrient Cycling on the Farm

For economic and environmental reasons, it makes sense for plants to more efficiently utilize nutrient cycling on the farm. Goals should include a reduction in long-distance nutrient flows, as well as promoting "true" on-farm cycling, in which nutrients return in the form of crop residue or manure to the fields from which they came. There are a number of strategies to help farmers reach the goal of better nutrient cycling:

Reduce unintended losses by promoting water infiltration and better root health through enhanced management of soil organic matter and physical properties. Ways organic matter can be built up and maintained - include increased additions of a variety of sources of organic matter, plus methods for reducing losses via tillage and conservation practices. In addition, apply only the amount of irrigation water needed to refill the root zone. Applying more irrigation water than needed can cause both runoff and leaching losses of nutrients. (In arid climates occasional extra water applications will be needed to leach accumulating salts from the irrigation below the root zone.)

Enhance nutrient uptake efficiency by carefully using fertilizers and amendments, as well as irrigation practices. Better placement and synchronizing application with plant growth both improve efficiency of fertilizer nutrients. Sometimes changing planting dates or switching to a new crop creates a better match between the timing of nutrient availability and crop needs. Tap local nutrient sources by seeking local sources of organic materials, such as leaves or grass clippings from towns, aquatic weeds harvested from lakes, produce waste from markets and restaurants, food processing wastes, and clean sewage sludges. Although cycles, the removal of agriculturally usable nutrients from the "waste stream" makes sense and helps develop more environmentally sound nutrient flows.

Promote consumption of locally produced foods by supporting local markets as well as returning local food wastes to farmland. When people purchase locally produced foods, there are more possibilities for true nutrient cycling to occur. Some community-supported agriculture (CSA) farms, where subscriptions for produce are paid before the start of the growing season, encourage their members to return produce waste to the farm for composting, completing a true cycle.

Reduce exports of nutrients in farm products by adding animal enterprises to crop farms. The best way to reduce nutrient exports per acre, as well as to make more use of forage legumes in rotations, is to add an animal (especially a ruminant) enterprise to a crop farm. Compared with selling crops, feeding crops to animals and exporting animal products result in far fewer nutrients leaving the farm. (Keep in mind that, on the other hand, raising animals with mainly purchased feed overloads a farm with nutrients.)

Bring animal densities in line with the land base of the farm - This can be accomplished by renting or purchasing more land - to grow a higher percentage of animal feeds and for manure application - or by limiting animal numbers.

Develop local partnerships to balance flows among different types of farms - This is especially beneficial when a livestock farmer has too many animals and imports a high percentage of feed and a neighboring vegetable or grain farm has a need for nutrients and an inadequate land base for allowing a rotation that includes a forage legume. By cooperating on nutrient management and rotations, both farms win, sometimes in ways that were not anticipated. Encouragement and coordination from an extension agent may help neighboring farmers work out cooperative agreements. It is more of a challenge as the distances become greater. Some livestock farms that are overloaded with nutrients are finding that composting is an attractive alternative way to handle manure. During the composting process, volume and weight are greatly reduced resulting in less material to transport. Organic farmers are always on the lookout for reasonably priced animal manures and composts. The landscape industry also uses a fair amount of compost. Local or regional compost exchanges can help remove nutrients from overburdened animal operations and place them on nutrient-deficient soils.

4. Nutrient Cycles and Flows

We used the term cycleearlier when discussing the flow of nutrients from soil to plant to animal to soil, as well as global carbon and nitrogen cycles. Some farmers minimize their use of nutrient supplements and try to rely more on natural soil nutrient cycles - as contrasted with purchased commercial fertilizers - to provide fertility to plants. But is it really possible to depend forever on the natural cycling of all the nutrients to meet a crop's needs? Let's first consider what a nutrient cycle is and how it differs from the other ways that nutrients move from one place to another.

When nutrients move from one place to another, that is a flow. There are many different types of nutrient flows that can occur. When you buy fertilizers or animal feeds, nutrients are "flowing" onto the farm. When you sell sweet corn, apples, hay, meat, or milk, nutrients are "flowing" off the farm. Flows that involve products entering or leaving the farm gate are managed intentionally, whether or not you are thinking about nutrients. Other flows are unplanned - for example, when nitrate is lost from the soil by leaching to groundwater or when runoff waters take nutrients along with eroded topsoil to a nearby stream.

When crops are harvested and brought to the barn to feed animals, that is a nutrient flow, as is the return of animal manure to the land. Together these two flows are a true cycle, because nutrients return to the fields from which they came. In forests and natural grassland, the cycling of nutrients is very efficient. In the early stages of agriculture, when almost all people lived near their fields, nutrient cycling was also efficient. However, in many types of agriculture, especially modern, "industrial-style" farming, there is little real cycling of nutrients, because there is no easy way to return nutrients shipped off the farm. In addition, nutrients in crop residues don't cycle very efficiently when the soil is without living plants for long periods, and nutrient runoff and leaching losses are much larger than from natural systems.

The first major break in the cycling of nutrients occurred as cities developed and nutrients began to routinely travel with farm products to feed the growing urban populations. It is rare for nutrients to travel many miles away from cities and return to the soils on which the crops and animals were originally raised. Thus, nutrients have accumulated in urban sewage and polluted waterways around the world. Even with the building of many new sewage treatment plants in the 1970's and 1980's, effluent containing nutrients still flows into waterways, and sewage sludges are not always handled in an environmentally sound manner.

The trend toward farm specialization, mostly driven by economic forces, has resulted in the second break in nutrient cycling by separating animals from the land that grows their feed. With specialized animal facilities nutrients accumulate in manure while crop farmers purchase large quantities of fertilizers to keep their fields from becoming nutrient deficient.

5. CASE STUDY: Nutrient recycling potential in rice-vegetable cropping sequences under in-situ residue management at mid-altitude subtropical Meghalaya (Das *et al.,* 2008).

5.1 Treatments

Treatment combinations consisted of five rice-based cropping sequences, namely rice–tomato, rice–potato, rice–carrot, rice–French bean, and rice-cabbage, replicated four times. The results were compared with the data obtained from the rice–fallow system (local practice) grown under similar management practices. Rice variety Sahsarang 1 was transplanted at 20 cm × 15 cm spacing in the first week of July. After the harvesting of rice, the field was converted into temporary raised and sunken beds (drainage) through which excess water was drained out through in situ drainage channels. After the harvesting of rice, the field was converted into temporary raised and sunken beds (drainage) through which excess water was drained out through in situ drainage channels. Only one intercultural operation, i.e., hoeing followed by earthing up was applied for all the vegetable crops. The crop was raised on natural soil fertility and the nutritional requirements of the crop were met through in situ incorporation of crop and weed residues. No crop residue, weed biomasses, etc. were removed from the field except the economic grain, fruits, etc. Harvesting of rice was done by cutting panicles close to the neck node, and the straw was chopped down using sickle. The chopped straw was incorporated into the soil using spade. Similarly, for vegetables only the economic portion was removed from the field and remaining residues incorporated into the soil.

5.1.1 Nutrient recycling through straw/ residues/ weeds

The production of rice straw, vegetable residues, and weed biomass is presented in Table 1, and their respective nutrient contents are presented in Table 2. It is evident from these tables that the nutrient content and removal varies for different residues. The highest N content was recorded in French bean residues (2.92%) followed by potato residues (2.90%), whereas P content was highest in radish residues

(0.25%). K content was maximum in French bean residues (2.02%), followed by potato residues (1.45%). Straw yield of rice varied from 58.2 q/ha in the case of rice–tomato to 65.62 q/ha in the case of rice monocropping. The nutrients recycled through rice straw varied from 35.1 kg N/ha with rice–carrot to 42.5 kg N/ha with rice–French bean, 9.6 kg P/ha with rice–carrot to 12.5 kg P/ha with a sole crop of rice and 78.6 kg K/ha with rice–carrot to 91.9 kg K/ha in the case of a sole crop of rice. The nutrient recycled through vegetable residues varied from 3.3 kg N/ha with rice carrot to 87.9 kg N/ha with rice–potato, 0.73 kg P/ha with rice–carrot to 6.98 kg P/ha with rice–potato and 3.6 kg K/ha with rice–carrot to 43.9 kg K/ha in the case of rice–potato. The nutrient recycled through incorporation of weed biomass varied from 56.3 to 75.9 kg N/ha, 7.1 to 9.6 kg P/ha, and 45.7 to 61.7 kg K/ha. The highest NPK recycling was recorded with the rice–potato sequence and the lowest with the rice–carrot sequence. However, highest amount of nutrient recycling was recorded for the rice–fallow system. Therefore, it is evident that the residues could almost supply the required nutrients for the crops, except for phosphorus. The higher amount of nutrient recycling with the rice–potato system was mainly because of the higher amount of biomass production.

Table 1: Nutrient recycling through rice straw, vegetable residues, and weed biomass into the soil (2-year average)

Crop sequences	Nutrient recycled through rice straw (kg/ha)				Nutrient recycled throughvegetables residues (kg/ha)			
	Biomass (q/ha)	N	P	K	Biomass (q/ha)	N	P	K
Rice–potato	62.93	39.0	11.3	86.8	30.33	87.9	6.98	43.9
Rice–tomato	58.17	37.2	10.5	79.7	20.22	43.5	4.0	27.3
Rice–frenchbean	64.39	42.5	12.2	88.8	4.55	14.5	0.86	9.19
Rice–carrot	56.54	35.1	9.6	78.6	3.67	3.3	0.73	3.6
Rice–cabbage	63.60	40.1	12.1	87.8	19.31	23.6	4.5	27.9
Rice–fallow	65.62	41.3	12.5	91.9	–	–	–	–
CD (P = 0.05)	5.31	3.56	1.02	7.42	2.30	5.23	3.23	3.36

Table 1 continue...

Nutrient recycled throughweed biomass (kg/ha)				Total nutrient recycled (kg/ha)		
Biomass(q/ha)	N	P	K	N	P	K
39.2	58.8	7.4	47.80	185.7	25.7	178.5
37.5	56.3	7.1	45.7	137.0	21.6	152.7
40.20	60.3	7.6	49.0	117.3	20.7	147.0
40.52	60.7	7.7	49.4	99.1	18.0	149.6
38.3	57.5	7.3	46.7	121.2	23.9	162.4
50.6	75.9	9.6	61.7	117.2	22.1	153.6
7.17	10.29	1.31	NS	18.72	3.33	NS

5.1.2 Nutrient removal by crops

The nutrient content and removal by rice grain and the economic part of the vegetables varied significantly depending on the different rice-based sequences (Tables 2, 3). In the case of rice, the highest NPK removal was recorded with rice–fallow followed by rice–French bean and rice–potato. Whereas, in the case of vegetables, significantly higher NPK removal was recorded with potato compared with all other vegetables. Cabbage and French bean recorded similar values of NPK removal. Total NPK removal was significantly higher in the rice–potato sequence compared to the other rice–vegetable sequences. While the rice–French bean sequence recordedthe next highest values of N and P removal, tomato recorded the next highest values of K removal.

Table 2: Nutrient content (percentage) of different biomass recycled into the soil

Cropping sequence	Available N(kg/ha)	Available P(kg/ha)	Available K(kg/ha)
Rice–potato	263.7	7.93	349
Rice–tomato	259.5	7.88	346
Rice–frenchbean	277.0	8.76	353

Table 2 Continue...

Table 2: Nutrient content (percentage) of different biomass recycled into the soil

Cropping sequence	Available N(kg/ha)	Available P(kg/ha)	Available K(kg/ha)
Rice–carrot	266.4	7.86	337
Rice–cabbage	252.2	7.47	328
Rice–fallow	268.0	7.67	348
CD (P = 0.05)	18.24	0.70	11.30
Initial	264.0	6.97	321

Table 3: Nutrient removal by rice grain and vegetables as influenced by residue management in different cropping sequences (pooled data)

Cropping sequence	Nutrient removed by rice grain (kg/ha)			Nutrient removed by economic part of vegetables (kg/ha)			Total nutrient removal (kg/ha)		
	N	P	K	N	P	K	N	P	K
Rice–potato	57.2	13.2	55.8	33.0	5.5	38.7	90.19	18.7	94.53
Rice–tomato	50.4	11.6	49.3	6.0	1.0	4.5	56.41	12.63	87.98
Rice–French bean	58.0	13.3	56.7	23.8	3.6	12.6	81.29	17.17	69.27
Rice–carrot	51.4	11.8	50.4	17.3	2.7	20.0	68.7	14.46	70.37
Rice–cabbage	55.0	12.7	53.8	22.3	3.4	20.2	77.37	16.11	74.05
Rice–fallow	60.7	14.0	59.3	–	–	–	60.7	14.01	59.3
CD (P = 0.05)	3.09	0.74	2.99	2.89	0.50	15.32	4.94	1.69	14.73

6. Conclusion

Therefore, it was evident that, under North Eastern Hill conditions, where tribal farmers hardly apply any external input to crop production, proper management of crop residues and other biomass can assure a fairly good crop in lowland. One additional pre-kharif (before monsoon season) crop can be grown profitably with residual moisture with proper land configuration. Rice–tomato or rice–carrot cropping sequences were found to be promising and profitable for lowland conditions. There is true nutrient cycling on most farms as crop residues or manures produced by animals fed crops grown on the farm are returned to the soil. However, there are potentially large flows of nutrients onto and off of farms, and we are concerned about cases where the flows are unbalanced. The inflow occurs as commercial and organic fertilizers and amendments as well as animal feeds are imported onto the farm and in manures and composts brought from off the farm. Exports are mainly in the form of crops and animal products. In general, larger amounts of nutrients are exported off the farm in vegetation (grains, forages, vegetables, *etc*.) than in animal products. This happens because a high percent of the nutrients in the feeds pass through the animal and are available as manure. And relatively few nutrients are exported per acre in the form of milk, meat, wool, etc., compared to the amount exported from crop farms. Nutrient flows are of such great concern because as nutrient levels decline, the soil rapidly degrades. On the other hand, when nutrients build up on the farm, they tend to be more readily lost to the environment.

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