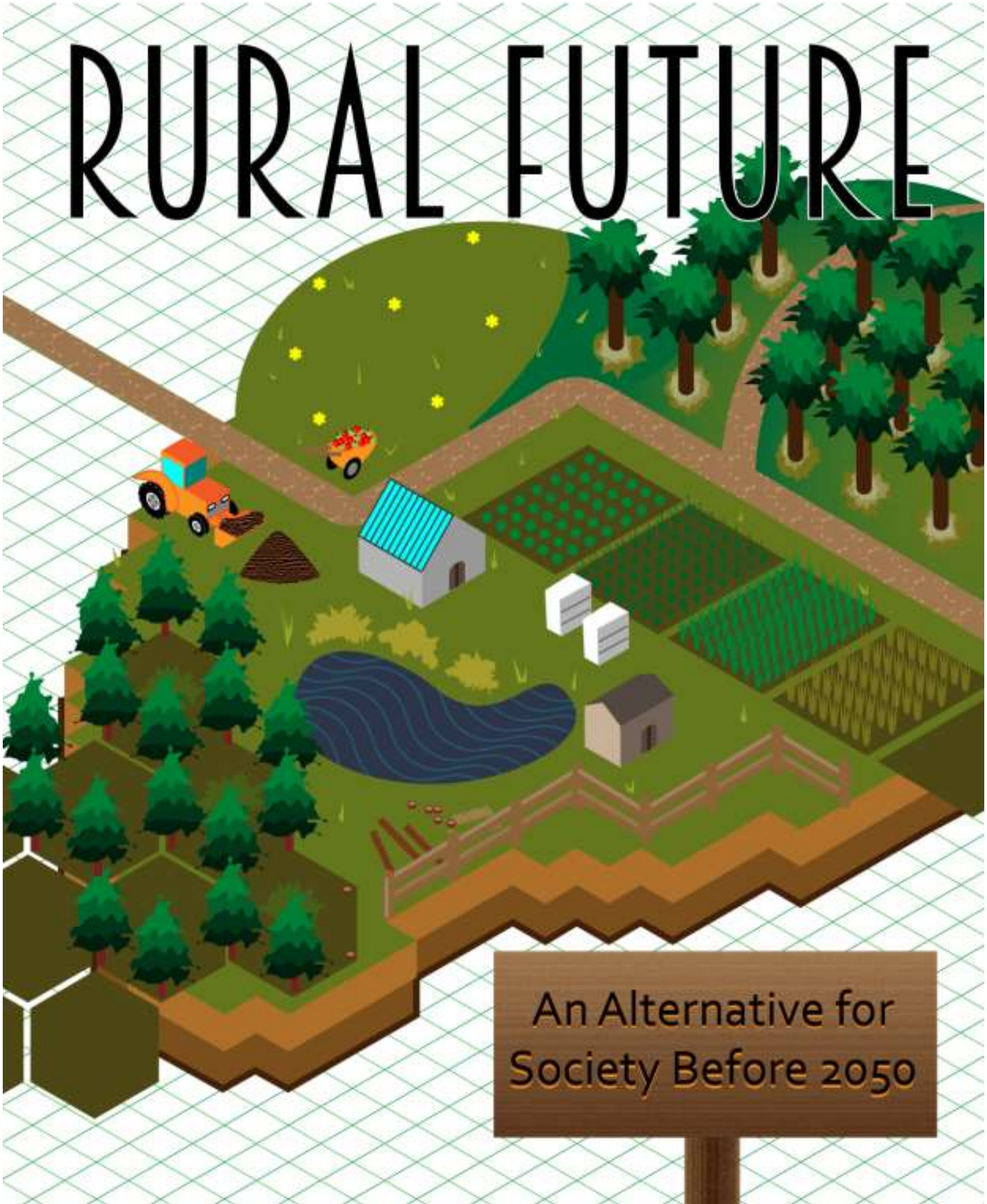
RURAL FUTURE
An Alternative for
Society Before 2050

Rural Future

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By: Robert H. Giles, Jr., Ph.D.

Edited by: Laurel Sindewald

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The Football Analogy

I remember a special day after retiring from the university. I had been thinking and writing about Rural System, as was common. I began watching American football on the TV and my mind turned again to the developing, potential Rural System corporation… perhaps "a Conglomerate"—and then a thought struck me.

The developing Conglomerate can use the analogy of American football. Of course, the leather football on the playing field is important, but the total football enterprise is very large and diverse. It includes uniforms, the stadium, food, drink, clothing, advertising, grounds, publications, fan clubs, and more. The ball is important, but compared to the greater football enterprise, the ball is almost irrelevant.

By analogy, the tree or the wild animal on the land is essential, but in the context of a total regional, rural, recreational, and viable economic land-use system, they are almost irrelevant. Perhaps people in forestry or natural resource management and closely-related activities have had their "eye of the ball" for too long. Perhaps just attracting visitors (as in ecotourism), or producing more wild animals has not served us well, and that it is now time to concentrate on the total rural and natural resource enterprise. More precisely, the enterprise can generate *profits* from beautiful, productive land, catering, lodging, equipment, products, organizations, and guides, etc.

By analogy with football, when it comes to the regional problems, we have talked about "ball handling" too long. We have talked about trees and fish and complained about environmental regulations. We've been "brought up" to ask for government help. We can ask for help, for resource protection, and broad-scale studies, but that has not been and may not be forthcoming. There has been little change after 50 years of spending carefully, well-regulated, the little that has been provided.

We (the farmer, the local natural resource specialist) are in the grip of all of the limitations of the single "cottage industry." We have rarely pondered the potentials of an integrated modern regional enterprise. We have been independent landowners, brothers and sisters of farmers! We can be independent... and meanwhile, lose something we hold in common: the vital county. We need an alternative model.

Later, the alternative was created; Rural System, Inc. was formed.

Chapter Seven

The Abiotics: Control or Response?

"Everything is related" is a truism, but naming, understanding, and moving those relations into computer forms for computations and improved decision-making (with payoffs and achieved objectives) is the quest within Rural System.

Wild faunal managers are really more than wild animal managers, and often deal with trees, shrubs, and other plants (flora). They often change and manage plants in order to cause animal populations (fauna) to change or stabilize in desired ways. "Wildlife," in general use, seems improper and imprecise, and is not often helpful in analyzing problems or communicating desirable actions. Though quite ecological since its inception, wild faunal management must now, as never before, be seen as very "abiotic" (not just the plants and animals) in expertise, unifying the forces of relevant environments, such as soils, geology, geomorphology, climate, and atmosphere.

Ecologists tend to be diversely interested in the biotic and abiotic, but quickly add to their study of plant and animal relations to each other: "and everything else." Foresters and wild faunal managers, too, see the need to add "everything else," as they work with sociological issues of tree harvests, tree density and soil and water relations, deer depredation on tree seedlings, hunters' damages, song-bird population density, road construction over trout waters, and visitor-views from forested roadsides.

We now see needs for useful hypothesis-making, gaining data and knowledge about the abiotic factors of the environments. Working with these now seems to be a viable strategy as we work to understand and gain predictive abilities for plant and animal supports of human populations, Earth-around.

Climate Change

New abiotic interests and emphases have grown. On Dec. 12, 2015, 195 countries agreed to reach for limiting Earth warming below 2 degrees C, or more specifically, 1.5 degrees by 2100 AD. Average global temperature is an abiotic factor of profound, sweeping, importance in all Earth-systems, an ecological factor that might be controlled, but is unlikely to be because of lack of understanding.

Failure will be seen in the continuation of climate change. CO_2 concentrations changed from 290 ppm (parts per million) in 1880 to 400 ppm in 2013.[1] That gas forms a transparent blanket over Earth. (It is imagined as if a cloud of smoke is the glass and plastic of a "greenhouse" over Earth.)

Greenhouse gasses will rise by 2100 AD, along with droughts, storms, sea levels, and coastal flooding… and will threaten 1 in 6 species of fauna with extinction. "*Change*" had better

[1] NASA. The Relentless Rise of Carbon Dioxide [Internet]. [cited 2017 Apr 21]. Available from: http://climate.nasa.gov/climate_resources/24/.

be the focus of university education and our proposed, educational PowerPlace (Chapter 11), as all specialists concentrate on the abiotic dimensions of their worlds, including land slope, aspect, elevation, depth transformations, evaporation, transpiration, wind velocities and major directions, albedo, moon-phase light mixes of those of lunar forces, and tidal forces… all at work in the global greenhouse… for good or evil.

Within Rural System we embrace energy conservation and alternative collections and uses, including solar, wind, hydro-tidal, wave, nuclear, and biomass. Still, we have little hope for success in limiting warming to less than 1.5 degrees by 2100 AD (coal, oil, and natural gas supply high amounts of carbon in the atmosphere, but even attacking these major sources will not likely achieve carbon reductions that seem needed).

Massive temperature change effects are unknown. From studies on important Douglas Fir trees, scientists found the trees relatively drought tolerant, and some trees more tolerant than others. Study-needs loom large for predicting the coming changes, their effects, costs, and specific responses needed for species survival.

The forests in America have been estimated to remove nearly 12 percent of total US greenhouse gas emissions, annually. These "emissions" include the estimated volume of extra carbon dioxide. Native forests have absorbed carbon dioxide, which has been variable over the years, but now both the amounts and variability have changed substantially.

There are already sets of strong cause-and-effect relations within changing climate, but also some resulting from human management actions and natural disturbances. Trees and other plants burned by wildfires give up significant amounts of carbon dioxide and other gases, and now there are conflicting, planned prescribed-burns in select timber-management procedures. Regional droughts complicate the picture (worsened by climate change, but also distinctly notable for reduced carbon fixation as wood volume and organic matter volume—generalized biomass—decrease). Insect outbreaks and invasions destroy plant materials and change growth rates (and thus carbon fixation). Not only the acreage, but the number of trees per unit area, the volume of the trees, and their photosynthetic and related physiological abilities to absorb carbon may be very dynamic.

One route of that dynamic is "diminishing." Forests are logged; forests may not be well managed; full stand stocking is rare; dynamic management plans for maximum carbon-bearing substance per unit area are rare. Of course, some forests on some areas are preserved. Some cannot be harvested, but even these are not managed for full carbon storage or "sequestration." Forested lands are changed for housing, airports, industrial development. Carbon in wooden structures is well-recognized as sequestered— “hidden away” —such as in long-term human structures where it is sequestered an average of 30 years.

There are some pressures to develop forest land into crop land, but most such commercially feasible transition has already occurred. New equipment for logging and transportation, and extensive energy use will continue forest-carbon losses, as well as rangeland-, pasture-, and soil-carbon losses. Carbon release to the atmosphere is not balanced by carbon storage, and one of the most likely and least costly now-known means to increase storage is within well-managed, long-term, planned forests.

The evidence is now seen that forests and organic elements cannot match the abundant, diverse human energy use of carbon-centric fossil fuels. While foresters and others wait, perhaps the best use of some last-available fossil fuel energy is to develop CO_2 collection and storage (as in well-known metal containers) ... since the rate of perfecting sophisticated forest-growth areas with massive, stable volumes (limited harvests, and protection from diverse 'forest-health' issues) seems unlikely.

Within Rural System we're trying to describe one way to clean up our mess in the air using managed forests, gaining our Earth portion of capacity for storing carbon. In doing so, we shall work with forests of each tract, gaining benefits for climate as well as those for groundwater volume, storm water management, soil vitality or recycling, birds and mammals, threatened plants, reduced erosion, and landscape visual wonders. Only continuously, intensively-managed forests can provide faster than normal additions of carbon in the storehouse of vertical trees—the carbon columns.

We see fire, insects, vandals, and thieves producing carbon leakage from our forests. We shall use wood for building, well-aware that net carbon storage benefits from using wood-based products are greater than such carbon benefits over time when using fossil-based energy-intensive steel, aluminum, plastic, and concrete. Wood products store carbon for hundreds of years; fossil-energy-based products have high carbon releases during relatively short lives.

The carbon stored within Rural System forests (and all forests) will always be changing as a result of forces and sequences of temperature, moisture, and a host of "ecological" factors and forest-stand factors, even including tree shape. We shall monitor the carbon (changing over a management period). We shall manage the forest, not a "collection of trees," with rotation in our work over areas to provide both insurance, base enhancement, and soil carbon. Total forest-captured carbon is our work, and we shall gain a recognized market value of the wood produced and secondarily-valued, relative benefits per acre:

- game species and aesthetic fauna;
- specialized "energy forests" (high-energy-bound-species) and arboreta systems;
- carbon estimates for all managed grass and forb fields, layer-one;
- thousands of cubic meters of layer-one soil carbon;
- reduced layer-one and layer-two carbon losses due to erosion control;
- groundwater volume additions related to managed forests and soil controls;
- reduced wind damage to structures and crops; and
- increased real estate sale value.

Costs of thinning forests are high, but thinning high-value stands can help achieve the objective, i.e., maximum solid volume and financial gains per unit area, stable over time to counter effects of changing popular wood prices. The cost is significant, both for thinning, but also as a part of stand management including harvest and replacement over extended years. Partial costs of management and replacement (replanting as needed) may be gained by sale of thinned wood and terminal-stand cuts.

Losses to fires, theft, pollution, flooding, and disease may initiate replacement costs, because the objective is typically maximizing the benefit/cost ratio, where benefits are strictly in this current crisis, total tons of stored carbon each year. It is very unlikely (a year here or there by accident) that a preserved forest area over 50 years from preservation data will match the stored carbon of a managed forest for 50 years on a similar site (or sites). Critical for combating climate change, carbon storage now "tops" other benefits. Decided harvest dates for each stand will differ because of a monetary criterion for harvest and a probable carbon-volume-weight growth criterion difference.

If climate change is allowed to happen, what will be the cost of the damage (presumably the repair work cost)? ... Should we try to prevent these costs, or pay later? Most such questions will be answered with GIS assistance.

It now seems clear that there is human-caused global warming of the atmosphere. Yet governments discuss prohibiting discussions of climate change in their courts! If not prevented, in Virginia climate change will result in sea level rise, increasing the coastline, increasing wetlands, but reducing the fertile coastal plain area. Hurricanes are likely to increase (due to sea warming), and their erosive forces in the uplands are well known. Ocean animal populations will change in unpredictable ways, thus birds that feed upon them will also change. Changes are predicted to be several decades away, possibly within a 20-year horizon.

Though there are global warming skeptics, scientific consensus now exists on anthropogenic global warming. A debate remains over specific impact predictions. The future cannot be known, only predictions made. Different models are used, and thus different results are expected. These include: between 1.5 and 4 degrees C by 2100 AD, 1 to 3.5 degrees C, and 0.5 degrees C. While the numbers appear small, they are enough to change an iceberg into water; prevent some fish from hatching; cause some plants to stop growth and others to progress too rapidly for successful fruiting; and some insects to hatch before their food supplies are available. Small changes over vast areas over many years can produce enormous consequences for people.

Xiao Zhang and Ximing Cai from the University of Illinois at Urbana-Champaign said that the amount of agricultural land available globally will change by only –1.7% up to +4.4% depending on the emissions scenario used.[2] Yet, this change will vary depending on the region. Zhang and Cai's estimates show that some regions of the world will gain arable land, while other areas will lose agricultural land in large amounts. Higher latitude regions, such as in Russia, China, and the US, may see total arable land increase by 37–67%, 22–36%, and 4–17%, respectively. Tropical and sub-tropical regions, however, are likely to lose agricultural land: South America may lose 1–21%, Africa 1–18%, and India 2–4% of arable land.

To respond further to climate warming (1-2 degrees C by 2050 AD) we must also address the re-encroachment of malaria and other mosquito and gnat-borne diseases. Water tables will drop, rainfall recharge will fluctuate more, and streams will have more variable peak-flow effects on fish and other organisms. Stream habitat of mayflies and other indicators of stream quality will change, and the indicators will thus become meaningless. Threatened aquatic snails and mussels, with their delicate, complex set of fish and habitat needs, will be compromised.

Major reductions in greenhouse gases—greater than 30%—are needed. Past changes to reduce our pollution have often resulted in profit gains. Perhaps the costs of change will be low and the suits and injunctions for industry by landowners who are harmed by the warming will be sufficient to make a financially-justified case of participation in halting global warming before developing nations prevent any reasonable remediation or recovery.

Rural System began developing a program for practical responses to climate change in 2013. We sought the advice of Mr. Waldon, formerly the head of Virginia Tech Conservation Management Institute. We hoped for national, international, and state action—a diverse, massive, coordinated effort—but we did not expect the high risk of likely inaction. We tried to develop a program within our 150-year planning horizon composed of:

1. Maximum carbon containment and on-site capture of carbon;

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[2] Liz Ahlberg. 2011. Study Predicts Large Regional Changes in Farmland Area [Internet]. University of Illinois. [Cited 2017 Apr 21]. Available from: http://news.illinois.edu/NEWS/11/0323farmland_XimingCai.html.

2. Maximum financial gains from various government and corporate sources related to carbon credits for such long-term carbon capture;
3. GIS-related techniques for documenting carbon-credit-related forest stands and facilities;
4. Planned response to near-future, costly climate-change phenomena on our contract and designated lands;
5. Selection of plants consistent with values but also resistant to temperature warming phenomena; and
6. Carefully-reflected messages furthering behavior to capture carbon and to reduce continued abundance of atmospheric carbon.

We hold that the climate is warming, thus weather patterns and precipitation are changing. Effects of these changes will occur locally and influence land use throughout. We are attempting, too late, to respond to climate change with the needed behavioral changes and preparations for our common future. We are limited; we shall work to those limits within this perceived crisis. Rural System staff will attempt to integrate science into decision-making, actively use the NOAA Climate Services Portal prototype (Climate.gov), and cooperate with others in bringing together climate science and services information. We shall actively translate related information from scientists into action on the land and water, and use active feedback.

We appreciate multi-national action in 2016, responding to real, inseparable problems. The problematic phenomena we examine and intend to model are:

1. Regional temperature-increase changes to phenology, hydrologic cycle, migration, and plant growth seasons, together specifying and limiting the plants that survive, their rates of growth, their likely disease and insect problems, maximum growth and health and susceptibility to frost damage—all of which can now be computer mapped;
2. Ancillary high winds and soil erosion depositions onto seedbeds, as well as increased tree blow-down events (accompanied by secondary effects, such as those of root thrust-ups);
3. Animal behavior responses to increases or changes in wind, such as, potentially, foraging aggregation and increased predation;
4. Accelerated evaporation;
5. Altered evapotranspiration;
6. Snow occurrence, sequences, and depths;
7. Changes in soil moisture;
8. Stream temperatures;
9. Base flow temperature changes, thus ecology of decomposition in those high-elevation, low-volume reaches;
10. Changes in seed germination and seedling survival, strongly related to evaporation;
11. Key insect abundance measurements in plant communities;
12. Rate of soil litter decomposition;
13. Rainfall and other precipitation events and amounts;
14. Debris slides caused by freezing and thawing (moisture weight buildup within soil);
15. Pond debris, plant-mat formations, and eutrophication; and
16. Forest dieback and injury to the conductive tissue of hardwoods, caused by extreme thaw-freeze cycles in winter followed by drought in summer.

Rural System's program for responding to climate change will include the following actions, not yet in preferred order or grouping but with data collected from public sources. These actions will be processed within VNodal, and will be issued as prescriptions for local actions, with alpha-unit precision:

1. Identifying changing management practices caused by knowledge of any/all aspects of climate change;
2. Furthering scientific knowledge or significant alternative knowledge bases (Chapter 5);
3. Listing and value-weighting resources likely to be vulnerable to such change and using the list to relate needs with priorities for action;
4. Relating vulnerable vegetation to strongly-related wild fauna, and other resources to "biodiversity" (carefully defined within the program);
5. Relating forest type/stand characteristics vulnerable to changes and forces;
6. Relating changes in riparian zone conditions to stream water quality/quantity, and then to fish and other notable organisms;
7. Relating roads, trails, and costs of access for tourism and work;
8. Relating rare or at-risk wild plants or animals on our contract lands;
9. Developing concepts of ecological resiliency; and
10. Relating ecological resiliency to economic resiliency within the System.

We progressively seek detailed strategies for handling the above, most of which can only be executed cost-effectively by in-house teams. We shall look for adaptations, substitutes, and careful cost-benefit analyses.

We'll work with others in a sub-project to relate changes in relevant variables to our riparian studies and those of the stream fishery and "Healthy Streams." Models will have to be used to explore the phenomena suggested here to reduce uncertainty and decision risks. Rising water levels threaten shoreline human communities, but also the areas for larval fish, feeding waterfowl, and marsh fauna. These waters need management, not just diversion. The wetlands of near-ocean shores require radical change from input analyses to implementing cost-effective priorities that will produce acceptable conditions for people for the likely future. Responses to shore-land proposals for change will have to include resisting development, as well as new management for riparian zones' coastal marshes.

The influence of insects on tree and understory plant growth, and food supplies for other insects and organisms, requires stressful, combined, coordinated observations of "services" for all normal functions from forests and streams—bottoms to forest canopies. Bark beetle outbreaks need special climate-change analyses. Trees, poorly spaced, are stressed by moisture excesses and shortages, and will begin dying, giving off pheromones that attract beetles. Observers will erroneously conclude that the beetles killed the trees, for they will see beetles on trees that are dying. Dr. Heikkenen's studies need further confirmation, but he showed the beetles are attracted to already dying trees (Chapter 4).

Climate change has a feedback function which we shall describe. Some forests will grow and store carbon; others will be intolerant, die, and the physical changes after death itself will add more carbon dioxide rapidly to the atmosphere.

We may be among the first to add specific gravity to our models of forest carbon and its capture or "sequestration." Foresters know the likely weight of wood of each tree species; we'll use this knowledge within our VNodal models with tree volume estimates. Thus, we see the pathway toward a software unit in VNodal to perform rapid, cost-effective forest ownership analysis for carbon sequestration. Owners, and Rural System, need to know now the range of consequences for participating in a carbon-capture program—costs, gains, timing—and how all these variables affect the bottom-line. A preliminary simulation will probably lead to knowledge of essential system components, provide sensitivity analyses, and point to cost-effective optimization software to be selected or constructed.

Precipitation and Erosion

We have had thoughtful work done by Rebecca Wajda on precipitation in Western Virginia Ecosystems.[3] We use major parts of that unpublished thesis as part of our direction, understanding of the available data, and perceived need for a climatologist or related specialists to work with us. We shall study and report on precipitation factors for each area, for these factors describe each area anew, previously known well only by long-term owners and assembled national and state databases.

We see precipitation on the ownership as action by variable, named factors of the abiotic realm. Factors of the area are influenced by measures of estimated monthly precipitation of all types. We study how to merge them, model likely conditions, and report on rainfall, snowfall, hail deposits and effects, evapotranspiration, analyses of precipitation chemical content, regional fog-drip estimates, and local records of cloud cover.

Vegetation buffer strips act as barriers to reduce soil movement on slopes.[4] We shall seek desirable erosion control efforts with vegetation in mountain areas, and thus utilize vegetation buffer strips for gaining relatively fast stabilization of disturbed hill slopes, gaining time for large-area control applications. Furthermore, timber and other vegetation will be harvested in a manner that will leave appropriately-located buffer strips.

We plan to study sediment deposits from wooded strips and those from nearby similar areas, especially as related to sediments likely to enter streams (not restricted to the banks of riparian zones). In the field, Rural System staff will need to use erosion soil loss equations to estimate loss/unit area given slope length (i.e., strip width), slope grade, and other factors later in equations combining Riparian Zone totals and pond dynamic volumes and borders.

Soils: Dynamic Places

As throughout this book, everything seems related to something, a function of something. There are relations, but few interrelations or *inter*-actions, the term often used within definitions of “ecology.” The study of relationships is of especially vital, lasting importance within soils of rural areas.

Soil names have been changed in the past, and so differ among countries and organizations. In addition, “soil” is an *overloaded* word including large to small earth particles, plant particles of recent or long-past organic death, soil solutions essential to plants, and some solutions that are plant killers. Soil may be called “polluted,” perhaps due to unintentional chemical spills, but other substances are added on purpose to kill or reduce an unimaginable number of different organisms, from microscopic ones to emerging “weed” plant roots.

Many names have been added to “soil” to suggest the range of differences, such as those of particle size—generally sand, silt, and clay. The combinations of these with organic matter,

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[3] Wajda RK. 1993. A site-specific rainfall model for Western Virginia ecosystems. M.S. Thesis. Blacksburg (VA): Virginia Tech.

[4] Heede BH. 1990. Vegetation strips control erosion in watersheds. Rocky Mountain Forest and Range Experiment Station. Research Note RM-499.

moisture differences, and in variable positions on the land create a complex substance that can be mastered adequately for the future with computer power. When these factors are combined with the dynamics of adjacent soils, history of use (and abuse), flooding, wind effects, past uses, and shading—among other factors—they produce evident differences, with unique requirements and limits for each plant species!

Rural System staff, well-aware of the challenges, are intent upon the analyses of soils within each Alpha Unit. We shall start with published soil data and maps, and load the cells with topographic data (such as slope steepness, aspect, and elevation). We shall also look for other spatial data from state agencies, commercial services, and from our own Studies Group, as we use acquired equipment and a small laboratory for each Alpha Unit. We shall combine such data with our computer access to precipitation and other weather events, daily, year-around.

We shall conduct separate studies of soil fauna—the food of mice, shrews, and earthworms—of many classes. Sampling methods will change with project interests and funding, and species information will not only be added, but will contribute local knowledge to active models influenced by feedback and set for improved decision-making.

Well-aware of forest site index effects on forest species suitability and growth, The Forest Group will work closely with The Soils Group. Diverse, rich soil is a base for mice and shrews, and *they* spread fungi throughout the top forest soil layers; fungi then transport dissolved soil minerals into roots of growing trees. Knowing, holding fast, prompting these relations, and stabilizing desired results will be parts of the jobs of all Rural System Groups as they work diligently for benefits and market products for a profitable future.

Rural system will continue to develop robust soil models in cooperation with state and federal agencies, especially in relation to data on appropriate uses of differently-named soils. One among many soil dimensions studied, and that we must further, is the soil carbon of "humus." We shall use the results of a study by Leak (1974): "Humus depths averaged between about 20 and 50 nm, depending upon the slope of the land (humus depth (mm) = 60.8-0.946 x slope %). The maximum single measurement was 101 nm."[5] We shall study parallels and try to quantify carbon amounts and dynamics throughout all Rural System areas, especially in advanced-age forested areas. With respected others[6] we know that soil organic matter (SOM) levels are "cornerstones of soil sustainability and quality assessments," but standards of goodness have not been established.

Since 50% of Earth's land surface is dedicated to agriculture, therein is "the largest terrestrial stock of carbon," thus Rural System's interest and action to understand its dynamics throughout our areas. We have concerns and seek "conditional" elements for definitions and other processes (drought resilience, sediment loads, and nutrient dynamics) that may together have measurable, consistent effects on crop yields.

Rural System staff have been actively involved in soil units of rural tracts for many years—from basic analyses through county-level soil and GIS applications, to a smartphone garden app for interpreting garden soil analyses. Rural System criteria for soil analysis include:

1. Estimating minimum diversity, at reasonable scale (similarly within no smaller than an Alpha Unit, within the scope of cost-effective allocation and singular characteristic);
2. Ready automation and adjacencies;

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[5] Leak WB. 1974. Some effects of forest preservation. Durham (NH): USDA Forest Service Res. Note NE-186.
[6] Wood SA, Sokol N, Bell CW, Bradford MA, Naeem S, Wallenstein MD, Palm CA. 2016. Opposing effects of different soil organic matter fractions on crop yields. Ecol Appl, 26: 2072-2085. doi:10.1890/16-0024.1

3. Characteristics easily, consistently measured, and recognized generally as likely influential to plant growth; and
4. Gaining separated results consistently for input to categories of:
    1. Slope,
    2. Flatness,
    3. Aspect (compass direction faced),
    4. Aspect type (a-conventional; b- coastal, inland, continental),
    5. Elevation,
    6. Vegetated type,
        a. none
        b. grasses/forbs
        c. forest seedlings
        d. pole-size trees
        e. trees, basal areas; height
        f. forest fire scarred, aged
    7. Soil organic matter (SOM),
        a. Zero inches deep and see above
        b. 1-5 inches deep
        c. 5 inches deep (average)
        d. Under water (ponds, streams, marsh, seep)
        e. Rocks and related (native rock, sand – no vegetation, solid cover concrete, etc.)
    8. Inches of surface organic matter.

The results from one perspective with which we plan work are "gross," but in a one-acre tract there are 43,560 square feet and 40.52 Alpha Units, wherein information can be automatically analyzed for answers to relations with other above-listed characteristics. The probability is small of finding reasonable, certifiable-for-use statistics within actual rural areas.

We recognize the costs, time, great variability and dangers, and shall hasten to master the above variables locally. We may converge on interpreting "soil health," resolving: does SOM volume per m^2 indicate soil health? If so, what aspects of soil health does it indicate?

We see that SOM may:

1. Store nutrients for sequenced uses and limit leaching;
2. Release nutrients from plant material;
3. Provide spaces for decomposers;
4. Provide energy and nutrients for decomposers;
5. Provide nutrient access to plants present;
6. Provide soil structure category;
7. Improve drainage;
8. Reduce erosion;
9. Influence surface evaporation;
10. Support wild fauna foods;
11. Store water;
12. Provide criteria for future definitions of soil health or farm/crop health;
13. Contribute later to food security;
14. Contribute to drought resilience; and

15. Decrease pond sediments.

We shall build SOM by adding organic matter to soil. We shall assess amounts of available organic matter (and calculate total needed for field coverage at a 6-inch maximum), observe the effects of our applications, and adjust in future applications to gain rapid, total integration of deposit, smoothly even throughout fields. We shall measure carbon capture based on our lab procedure for allocated volume/acre to produce desired carbon levels. We may develop a strategy to build proper SOM for each crop and for carbon capture (likely in conflict with SOM). There's interesting work ahead.

Functional soils, feeding plants as well as providing support, provide plants nutrients dissolved in waters. Rural areas of the US, and many throughout Earth, face water shortages. The problem is no longer secret, and faces all of Earth's people around 2030 AD.

"Water crisis" sounds unimaginable in many regions of Eastern USA; proof is that people will not imagine it and act upon such knowledge. As fertilizer is needed for plant growth, so too is clean water—irrigation to enhance or achieve adequate crop and livestock production. Fertilizer supplies, now costly and insecure, must be carefully managed within the waters supplied to plants.

Glaciers melt, and now this "extra water" (from the recent past) causes the sea to rise over coastal areas, thus salt-water splashes over and into once-crop-rich lands. I've visited areas where well-water for humans is now unusable—too saline—wells closed!

I worked with a graduate student years ago who wrote a Master of Science degree thesis exploring optimum computer pathways for sending "cool-clear-water" from Virginia mountains to its massive, urban coast. The needs are not new; alternative sources seem needed… but not as much as restricted preferential uses, greater care, massive storage, and best-use policies developed for an increasing human population (and with world populations experiencing effects of variable climate change dynamics among 190 or more countries).

Linked: Stream and Pond Systems

There are many other factors influencing crop success, but water is significant, and performs only under a long, complex set of conditions: timely abundance, access, competing demands, nearby climate conditions (affecting land preparation), and plant-seed germination and growth. But as Dr. Tamim Younos, president of Green Water-Infrastructure Academy, writes:[7]

> Water is a limited resource. Water demand for energy production and electricity generation is increasingly in competition with potable water demand and food production. To cope with this challenge, energy conservation and developing renewable energy technologies with high water use efficiency are critically needed.
>
> This can be accomplished by adopting, where feasible, a multitude of decentralized and water-efficient renewable energy technologies such as wind, solar photovoltaics, geothermal, bioenergy, micro-hydro and other developing

[7] Younos T. 2016. Younos: Energy use and water resources impacts [Internet]. The Roanoke Times. [cited 2017 Apr 21]. Available from: http://www.roanoke.com/opinion/commentary/younos-energy-use-and-water-resources-impacts/article_141c09a9-dd19-53ce-bb44-5e4cc6418f27.html.

innovative energy technologies. Policy and economic incentives should support this challenge.

The need seems great—a lasting, giant intertwined challenge—to be met and solved in major proportion before 2030 AD. Rural System trembles under the weight, though hopeful, and plans to develop local, small, integrated irrigation systems, water-capture systems, and careful-use systems.

Water management is so fundamental to management of all aspects of rural systems, yet it and its complexities are assumed "handled" by "unnamed others." Except in river, lake, and urban centers, abundant water cannot be used to explore the effects of relative water abundance on very diverse ecosystems. Yet, though it seems excessive and "reaching" to call water a "trophic currency," it has unlimited use, value, possession, and roles as "food." The elements of management (to be handled by The Water Group), rarely listed, require attention to the following:

1. Plant species requirements—seasonal and group
2. Topography—slope and aspect
3. Elevation—freeze period and degree days
4. Floodplains—area and effects
5. Animals present
6. Precipitation—amounts, and sequences
7. Leaf shade, fall, and collection mass—leaf mass forming moisture, and its dynamics
8. Ground water storage and evident movement
9. Soil moisture (influencing leaf mass moisture, forest root extension in moisture, and thus "site index," an expression used by foresters to describe the quality of an area for growing trees)
10. Prescription (of small, very local manipulation)
11. Proximity to wind, evaporation, and evapotranspiration sources
12. Fog drip—amounts and timing
13. Local xeric plant options for significant water quantity losses
14. Plant species proximity, and shadows cast—influences to water storage or evaporation
15. Temperature, affecting suitability for organisms in soil solution formation
16. Timing of moisture presence and absence
17. Related effects of specific land irrigation in forest and range fires and extended drought
18. Scouring effects of floods
19. New aquatic mixtures from floods, storms, and irrigation

Virginians, as others, have given lip service to water being the basic resource. Worn phrases on the value of water, the quantities used, and complete human dependence upon it are abundant everywhere. What has been said and what has been done on the land are unequal; the words are far more impressive than the actions. There are exceptions in our broad view of watershed management and hydro-systems, but they are few.

The topic of watersheds or their management is frequently given cool reception, or the conversation quickly turns to so-called "watershed laws." Aldo Leopold decried this attitude, saying that, "The real substance of conservation lies not in the physical projects of government but in the mental processes of citizens." The management of the source of water is so important that it must be thoroughly understood by everyone, from park sitters to successful agriculturists and miners. Mental processes must be cultivated so that citizens in a properly-functioning democracy realize their part in the “physical projects,” especially those projects and units of knowledge affecting water resources.

The technical aspects of watershed management are complicated, but the basics are within reach of almost everyone. It is oversimplifying to say that good soil, forest, and wild fauna management are good watershed management. True enough, people seldom go out and “practice watershed management” like they might “plant a forest” or plant an area with wild fauna foods. Watershed management is an integral part of every sound land resource practice. It must be a basic consideration in every wise decision on land use. Watershed management, like other resource responsibilities, cannot be left to “someone else.”

Within Rural System, we now stress and study watershed and stream relation and add the concept of **Crescent** management, to emphasize new approaches and intensities for future studies of headwaters and those large, often-mountainous land triangles that exist between adjacent streams flowing down toward a common large stream or river.

Near the Top of the Crescent

There is abundant historical interest in landscapes and growing interest in landscape ecology. Previously, I discussed rural land areas that need to be studied and exploited to gain precise, predictable, timely control of all “scapes”—landscapes, odorscapes, soundscapes, and viewscapes (Chapter 2).

“Watershed” is a fairly well-known word but I shall not risk personal depression in testing such knowledge or its limits. (It has several definitions.) It’s an area with ridges of land within which rain and other precipitation and waters from small streams flow, and then collectively flow to larger, similar areas, then to rivers or seas. Their shape is like half of a pear, cut top to bottom. They are where trees and crops grow, streams discharge their waters, ground waters are recharged, flood waters form, and where streams become rivers.

A little thought immediately discloses that every unit of land is part of a watershed. These statements add up to *the structure or basis for a total, sound program of watershed management that may ultimately reach the national, even the world goals of wise land use.*

“Comprehensive watershed management” might meet the needs seen for the future, but as comprehensive and as powerful as its past research and applications have been, it is not sufficient alone. “Crescent management,” described herein, is intended as an escape from the institutional, corporate, and educational limits imposed by past use of the term “watershed” in meeting the now well-seen needs of unification: ocean edges to mountain tops, past to likely future, and glass-full to aquifer-empty.

Crescent is a proposed plan for an Alpha-Unit-precise land and water management system, and includes the fishery (discussed later in this chapter). We can make large area maps of rural streams, ponds, and Crescent boundaries based on elevation maps. Inside a Crescent boundary, we can load all of the Alpha Units, and specify the aspect of each Alpha Unit as well as over 50 other ecological factors.

Past watershed management has not been adequate. The usual objectives of watershed management are to provide required yields of water, and to prevent damages from floods. Herein, we propose to add dimensions of water quality, risk assessment, and minimizing costs, as well as profits from sports, diverse uses, wildlife observations, and more.

There are two apparently-opposing objectives. On one hand, the need is to produce water, on the other, to control and clean it. In Virginia, as throughout the nation, there are areas of critical water shortage. On such areas, increased water production, collection, processing, and delivery is demanded from the watershed planner. Other areas are flooded annually. The people of these areas demand less water, greater directional controls, removal, or restrictions on when and how to use flood danger areas. The solution to such an apparent dilemma can be reached by informed citizens, and the actions of *Crescent* managers.

In the past, many people have falsely rationalized that: water is closely linked to climate, people can do little about the climate, and thus people can do nothing effectively about water supplies. Some government projects have done something with water, and made an active program of watershed management. Many times, defensive or rebuilding programs were inadequate, requirements massive, land-use change effects on water unpredicted, and control limited.

Gaining comprehensive knowledge is very difficult in any field, particularly one as complex as watershed management. Educating all resource workers with such knowledge is a mere dream, yet its importance must not be treated like a dream. The only option available for reducing poor decisions, avoiding counterintuitive results, and improving water management, is a highly practical, highly accessible, dynamically-improving computer system to assist the resource worker. Such a system, with a small group of highly-educated advisors, can make significant changes in the way lands are managed. Computer systems can be used at all stages of land use, from preplanning, through daily work and reclamation, to monitoring and evaluating final developments, and making useful adaptations to local conditions for the near future.

Previous systems, such as those developed by my former students, were designed to face some harsh and embarrassing realities about watershed models in general, and to present knowledge about soils and water relations in managed or mined areas. Trips to the moon notwithstanding, scientists do not know or cannot confidently estimate likely site-specific changes in overland and subsurface water flow, and related sediment losses, in forests and other terrain, or their distributions in time, space, and stage of plant after rain or snow. For example, snow melt rates need correlations with diverse field conditions. We need to unify such knowledge in computer models, add recent study results, and use new electronic information transfer capabilities for rapid use in rural areas.

Computer models, with active feedback forces, can be improved. There are a thousand streams to monitor; there are ten thousand times that many dollars required. *The studies will not be done in realistic time!*

An option is needed. The answer is *relative* models, using the best possible relations known, the least possible inputs, and maximum computer transformation and correlation of data, producing practical decision aids for the manager or decision-maker.

The needs are thus for robust models based on physical laws and phenomena. We need those that are modular so that whole “chunks” can be replaced as knowledge expands, those that are balanced or have proper regard for significant figures, and those that are sensitive to the wide variety of changes highly likely in a multi-factored system, i.e., one that can be plus or minus 10 orders of magnitude different even with complete knowledge! Models are needed to seek even improvements of one-half-of-one-percent in decisions, because a small percent improvement in 100 areas over 150 years is a massive change.

We have seen that for many watersheds studied, about half of the map cells in a single watershed face different directions (have different aspect), which means different sunlight, rain runoff, snow melt, evaporation, groundwater recharge, forest site index, and insect and disease habitat suitability. We must cease over-generalizing for *watersheds* and allow computer processing of *Crescents*.

We shall work for specific, multi-factor precision management of named map areas. The map of the likely ridge-crest-center is no longer as important as it was once; now it is only a single map factor among hundreds, and their thousands of combinations. Fog drip, for example (that beautiful, rare frost seen on tree and shrub stems), is capable of causing differences in perceived precipitation up to 10-25 inches in local forests.

"Crescent management" is a decided choice between "whole-stream" and "formerly-watershed" management, in favor of the former. It is concentrated work, from observation to working model, of the whole Crescent area—every Alpha Unit, and every known or hypothesized factor affecting or affected by the whole stream.

The stream is statistically the "dependent factor," the mappable unit, evident flowing-water and its related land, a dynamic entity. The whole-stream is perceived, minimally, as a function of other systems. For example, the climate and upper hydrology of adjacent Crescent units are interrelated, as are the hydrology and geology of adjacent Alpha Units, including stream-bed elevation (stream-flow rate), geological layers, "placements" observed in influencing significant stream change (e.g., geological features, or forest trees), and stream barriers such as constructed ponds, dams, and roadways.

Within Rural System we shall work toward a crew that can effectively enter and embrace the full needed measures of a Crescent, and cost-effectively move these measures into models and useful graphics to aid in policy formulation (e.g., required monitoring and data-updates and reports; dependence on human food production or removing barriers) that balance competing demands and visions for each stream system, adjacent ones, and evaluation to stream-based riverine system influences.

Rural System (as suggested by Poff et al., 2003[8]) will seek funding partnerships, but will form a unique, membership-based organization for two Rural System Groups devoted to streams, and thus to climate dynamics and river ecosystems and their management. We understand the diversity and complexity of streams, and see riparian volumes as part of the effort needed for "whole stream" work—with assured payoff.

We know the needed monitoring to gain flow rates … one major function of the perceived "whole stream," and then to contribute to whatever riverine flow is encountered. With others encountered in stream-life interests, we'll hope for mutual aids as we discover and try to match species with conditions (using GPS and GIS) that may be replicated for increased species' safety and existence. We need to know that we can increase a limited population of aquatic or riparian volume species to become convincing in meeting the costly needs of effective species restoration, including "certified" past stream flow dynamics and their flora and fauna.

The stream or river is the performance measure of the working land system. It can be depicted by annual hydrographs and thermographs, both of which are primarily determined by the surface geologic and geomorphic setting, and vegetation cover of the stream sides. We know of and can model each of the fluvial processes—geomorphology, channel form and equilibrium, bankfull, hydraulic forces, sediment transport, sediment budgets, sediment sources, and even how geomorphic processes affect statements of stream health.

[8] Poff et al. 2003. River flows and water wars: emerging science for environmental decision making. Frontiers in Ecology and the Environment. 1(6):298-306.

We start at the top, along the mountain edge or crest. There is a mystery in the Crescent, faced by every forest worker who must mark for mapping the watershed boundary and the upper origin of a small leaf- and debris-hidden rural stream called the *headwaters*.

Pinning flags into the border of a watershed, or "Crescent," may be easy in rocky areas or tall forests. Just where is the center line where water (if even present) no longer flows toward the stream being mapped? Where is the place with the fewest steps that will allow an imaginary line to be cast where imagined water will move to a collecting center stream? Where is the point at which a stream most likely can be observed, and marked on the ground as the "start," or the headwater origin?

A headwater stream may be invisible for a distance. Some run under leaves, wood and soil, and are very much a function of visible topography or season of the year and time since the last rain... the stream eventually "shows." That place, a point, is unique and nascent, and will likely be changed with time and many factors. It needs to be marked, and the dynamics of the point need to be noted in order to understand the stream and the life within it.

Headwater streams are at the origin, a linear feature at the ridge or mountain top. The riparian volume stretches from below the running water to several meters on each side, and then to the top of streamside vegetation (the system of a named upper-length of stream, called a "reach" within some areas). The volume is likely to be a dynamic area (soil, litter, limbs, tree bole, etc.), contributing very diverse life and substances to the stream below. The edges, like forest "seeps," may harbor life forms unlike those found elsewhere in a Crescent.

Riparian areas of the Crescent, "where the terrestrial mingles with the aquatic, are special places... they have strong ecological connections to uplands and provide resources to the downstream system," wrote Szaro (1990).[9] We suggest work with the riparian volume of Crescents, perceived invaluable sites for the future.

We shall observe the distance from the stream to where aquatic and terrestrial amphibian assemblages rely on the stream and riparian habitat, and attempt to manage a zone of 10 meters from stream to ridge line. Larger trees ultimately lead to larger pieces of down wood, which form critical, diverse faunal habitat both on land and in streams. Tree growth is great where headwater streams are nearby. The streams provide continuous water, special habitats, high carbon capture in associated trees and soil, and ground cover.

Diverse salamanders need a minimum distance to move—from headwater stream elevation to up and over ridgelines—to achieve gene flow. Preservation/management is also needed for large trees for creating habitat at these high headwater sites for refuges and essential travel areas/zones for salamanders, terrestrial pulmonates (snails), and some key insect species—all related to micro-climates, litter fall, substrate mixing, sediment flow, and faunal diversity.

After study results, we are likely to see clearly the need and potentials for (1) protecting head waters; (2) making presentations, visits, and teaching about their differences, roles, and importance; (3) making new comparisons with forest seeps; (4) providing and assuring trail crossings with local protection; and (5) suggesting GIS analyses of potentials for "over the ridge" movements of diverse genetic populations within these type-1 stream sites.

A "Broke" Fishery

[9] Szaro. 1990. Southwestern riparian plant communities: Site characteristics, tree species distributions, and size-class structures. Forest Ecology and Management 33-34:315-334.

Much research in watershed management is needed. Local monitoring stations are needed, but the first order priority is for a fully-operational, highly interactive, permanently in-place and operating computer system to aid the practicing field person. It is now possible to rapidly digitize the watersheds of an area, or to use watershed boundary software that locates the "edges" of watersheds. These maps can become overlays for dozens of other GIS layers including slope, aspect, land cover, soil depth, and forest type.

The entire water drainage, within boundaries, may be digitized and analyzed. That is, all streams within the boundaries may be digitized, and third-, fourth-, and fifth-order watersheds delineated. Any areas which do not fit into these watershed boundaries may be divided into similarly-sized management areas. Worksheets may be produced for each watershed area; perimeter, and line length data taken from the digitizing process; and elevation data may be coded directly from the maps. The ownership boundaries may also be traced onto maps.

I've discussed the Crescent, the revised concept of land and water management within which streams exist. Fish live there, as do many other organisms and diverse resource benefits. Writing this chapter makes me sad, for I've seen vital streams in Piedmont Virginia, and mountainous Augusta County, Virginia, and have heard tales of trout in feeder streams of The James River. I've turned over rocks looking for seasonal insect larvae. Dr. Ken Hungerford taught me about the underwater walking bird of Idaho mountain streams, the water ouzel. I cried beside a stream near Oakridge Oregon, for I had known it at age 24 and knew others would not see it or understand what they saw, and that, working then to have significant impact on such beauty and functions for the future, I had been, and would remain, a failure. I did not have the tactics, tools, temperament, or power to save the stream… and lived a continent away. My possible impact on rural streams was small, germ-like.

Back home, I've tried to forget the shacks near the orange waters of western Virginia, and drives along streams beside coal-dusty modern houses, too-close to streams within the coal-fields. I try to forget the audience member of the late meeting who appealed for a clean stream cleanup so that people living along the stream could again be baptized there.

I knew a small, rushing mountain stream in a National Forest within my wildlife management area in Virginia. There were hundreds like it. Most of them had once held brook trout. Conditions suitable for the "brookies" had been lost, over-fished, and once-remembered "trout water" were stocked with brown trout, not the native brook trout. I had begun learning about "a fishery," a little like a system, with mixed objectives (being in mountain-forest, fast water, wanting "bites," being in touch with nature, past excitement, family tradition, possible contests with family, and contests with the fish themselves).

All fishery objectives are dependent upon natural forces. The angler is aware of the beauty of the adult fish and conflicted over whether his caught fish is "native" or "stocked," among dozens of other questions: stream scale and velocity, the floor beneath the stream rocks, new fishing flies, vegetation in the stream zone (producing foraging insects—fish food), and new challenges of disrespectful "other anglers" seeking an outing and not a fish.

Yes, a *fishery* is a thing—a whole sociological, hydrological, entomological, geological, ecological, ichthyological, ornithological, geomorphological, economical *thing*. So far it has had no clear objective, thus no means for feedback, and many obscure processes, inputs unsorted and unanalyzed for named uses, an uncompiled history, no standback to await the changes in groundwater and surface water before 2030 AD, and no one to name the context for the social challenges of a hungry human population in 2050 AD.

I learned, when working above that stream in Oregon, that every stream, especially every reach, was unique. I knew then that I did not *know* the stream—it could not reveal its complexities. And though I had known it longer than many others, it would not last; visitors would see only its edges, if at all; for it was now all dressed up with a parking lot. The fish were safe, never to be harvested or otherwise appreciated by people.

In some areas streams are problems, impediments … somehow abnormal, thus not natural. Some are not recognizable, so unwanted and so polluted that Total Maximum Daily Load of pollutants is written or said so often, people just mumble TMDL.

I've had wonderful drinks of cold stream water when I was a youth, camping in Virginia. I cannot now, for the water is too dangerous … everywhere. It makes me sad, not "crying sad," just childhood-depriving sad, fresh wonderment lost.

There can be only one way for a modern stream resource to emerge. It won't be justified only by counts of fish or counts of anglers. Not fish, but a modern fishery creates a *resource* and maintains it for many people, for many years, with many benefits. The needed and named benefits are associated with waterfowl, fur-bearing mammals, aquatic insects (seasonal), foraging snakes, raccoons eating crayfish (those crayfish just missed by a wild turkey), and anglers from near and far. Managers must consider, too, anglers' tackle and clothing, and their bait—whether handmade by wounded warriors or cast-aside late in the day at the stream edge as "worm pollution" (mixing the genetics of earthworm populations, local and distant, without an extra thought). Who can or will call *"danger ahead"* before the first trauma, or apparent wellness is lost?

In Rural System, we see potentials within a complex, comprehensive fishery. Not "broke," we need one that can expand to meet some of the food needs becoming clear in 2050 AD. The task is to expand a diversely appealing, job-creating, money-raising, Crescent-enhancing, recreation- and tourism-satisfying *modern resource.*

From fish, like the "canary-in-the-mine" may come our warning signal for the condition of Crescent areas and widespread land quality. Rural System plans elements of all of the above, for streams need to be seen, understood, visited, experienced, protected from a dozen challenges, and improved. Each fish species can tell people much about water quality. As a source of food for future human populations, trout streams are not the place to depend upon. Factory fish are needed to meet human food needs. Instead, the trout stream is our warning system, sensitive as it is to the conditions of the whole Crescent.

One in three Americans, or about 117 million people, get their drinking water from public systems that rely on streams.[10] Streams and wetlands provide many benefits to communities: they trap floodwaters, recharge ground water supplies, remove pollution, and provide habitat for fish and wild fauna. They're also economic drivers because they support agriculture, outdoor recreation, energy, and manufacturing. Science shows that streams and wetlands are vital to our health and the environment, so Rural System is committed to protecting them.

I visited China some years ago. That country's economic growth is reported to have been hindered by a shortage of fresh water. Experts there introduced a Water Agenda in 1998 to reduce shortages, pollution, and wastes, to increase better uses, and to reduce problems with

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[10] Ortiz J. 2014. EPA and Army Corps of Engineers Clarify Protection for Nation's Streams and Wetlands: Agriculture's Exemptions and Exclusions from Clean Water Act Expanded by Proposal [Internet]. Environmental Protection Agency. [cited 2017 Apr 21]. Availble from: https://yosemite.epa.gov/opa/admpress.nsf/3881d73f4d4aaa0b85257359003f5348/ae90dedd9595a02485257ca600557e30.

flooding and erosion losses from storms. They are integrating water resource management and working with the private sector to solve water shortage problems, all while safe-guarding desirable socioeconomic development.

They understand the UN warnings about a great imbalance between likely water availability and use by 2030 AD. I think that Rural System, too, must concentrate on that date for all of the regions with which we work. In beginning a systems strategy, we approximate our objectives. Our general system objectives were discussed in Chapter 2, but each subsystem in Rural System must have its own clear objectives, including **The Fishery**. The modern Rural System fishery enterprise will work to:

1. stabilize or increase diverse, stream-related benefits and profits from meaningful work;
2. stabilize and enhance existing streams of Western Virginia to meet high standards of structure, function, and relations to their surroundings;
3. provide knowledge and services to repair, restore, and enhance streams that do not meet owner or government-sanctioned requirements and standards for healthy streams or their water quantity and quality;
4. minimize grief of fish removals (angling) and other losses; and
5. provide advice and services for landowners to gain economic advantages from their streams.

There are many prescriptions to be completed toward achieving these objectives. The primary ones include:

1. Implement minimum stream stabilization and improvement practices;
2. Work to achieve headwater stability;
3. Improve or redevelop forest and farm roads;
4. Carefully and precisely develop a *riparian volume* plan, protective of the stream, its surroundings, and benefits;
5. Implement a Crescent strategy with minimum silt as a monthly water quality requirement for the outlet waters;
6. Integrate local studies and work for the region near neighboring federal areas;
7. Treat each stream as a unique resource to be visited, photographed, analyzed, and characterized;
8. List and develop financial gains for each stream: art, pictures, booklets, special fish tournaments, tagged fish (rewards for capture), and paid visits to see and learn the fish of each stream;
9. Conduct high-school classes, and Eagle-scout and adult organization stream-improvement expeditions;
10. Develop a pattern for characterizing a stream and assign a numerical scale value;
11. Design signs identifying stream functions and workers;
12. Conduct bus-load visits of adults to streams with campfires and music; and
13. Teach units about **The Crescent Strategy** and **The Riparian Volume**.

The Riparian Volume

Riparian areas or zones are vital edges between terrestrial and aquatic ecosystems that have a wide range of ecological functions and associated social benefits. They're the land and community along the sides of fresh, unbound water. The lower 48 states have about 900,000 acres of riparian zones. Healthy riparian areas maintain cool water temperatures, clean water, stable banks, aquatic diversity, wild floral and faunal habitat, landscape connectivity, and water flow, while providing wood, other forest products, energy, fish, and recreation for people.

Riparian zones have vegetation and physical characteristics that reflect the influence of permanent water. Lakeshores and stream banks are typical riparian areas, but certain ephemeral streams or "washes" are excluded that do not exhibit the presence of vegetation dependent upon free, continuous water in the soil.

Within Rural System we shall use and promote the concept of riparian volumes. Riparian "zones," are really volumes with width, depth, height, and are very dynamic. The riparian volume usually supports vegetation significantly different from that of adjacent inland areas. Some people argue that riparian zones are ecosystems between the aquatic and terrestrial, but this concept omits the stream itself, inseparable from the riparian volume.

Eventually, riparian areas will have to be faced as *dynamic volumes* influenced by adjacent tree canopies; the bottom of the still-explored hyporheic zone beneath the stream; the stream and its parts, floor, and surface; the ever-changing stream age, edge length, elevation, width, and depth; and flora and fauna. The riparian zone is a dynamic, 3-dimensional volume to be investigated… forever.

The Context

In general, Earth has an abundance of water. But only 4% of this water is fresh, and three-quarters of that amount is frozen in polar ice caps. That leaves us with just 200,000 cubic kilometers of useable freshwater, less than 1% of Earth's total freshwater resource. Most of this available water is found in groundwater aquifers, rivers, and lakes. The fishery works on the spaces and volumes of streams feeding and being fed by the groundwater.

Rural System plans to create an enterprise that profits from analyzing, restoring, and continuing to manage small streams on private lands in a region of Virginia. We will characterize and document our work, and provide the landowner with certificates that can be sold to a specialized stream-mitigation credit bank. We shall work with such banks.

Developers in the region may significantly modify streams in their construction, but are required under law to mitigate those changes or losses. They can avoid such losses, make changes on-site, or they may buy credits from the bank. The credits certify that within the relevant watershed and/or region of Virginia, a stated number of linear feet of restoration (dimension, pattern, and profile) and/or linear feet of enhancement (in-stream structures, bank grading, bioengineering, matting, and revegetation) have been developed. Habitat types (riparian hardwood forests, wetlands, etc.) present are specified as required for some mitigation.

We shall offer services to highway, airport, railway, governments, and other developers who impact streams credits through **The Healthy Streams Group**. Developers now need stream mitigation under national and state laws, personal concerns, and "green" policies. We'll supply guaranteed, full credits under Corps of Engineers and DEQ standards.

We shall market stream work to private landowners, showing direct economic returns to them from our action, stream improvement for personal use, improved livestock returns, reduced soil losses, improved groundwater recharge, an improved fishery, improved wildlife habitat for many stream-related species (e.g., bear, fox, bobcat, raccoon, mink, waterfowl, several songbirds), enhanced scenic and land-sale value, reduced risks (flooding, suits, etc.), and access to several funding sources within Rural System related to streams and nature study.

We shall differ from other, similar groups in years of experience, fundamental knowledge, available software, and GIS developments of stream and watershed characteristics and surrounding lands. We are also concerned with carbon credits on the same areas, having ancillary work units for later development, and having a vision for the whole future enterprise. While working hard to slow climate change, we have within our plans preparation for responding to increased storms, droughts, and water pollution problems that are becoming more frequent and severe as temperatures rise.

Managing the Streams

Rural System will deal with total stream systems, a major part of which is the total fishery. Only one part of the fishery will involve geographically-focused, scientifically-based work to protect, restore, and enhance the freshwater stream aquatic habitats and the watersheds upon which they depend.

We know that stream watersheds are very variable and contend that each is unique (hence Rural System Crescent management). To study a group of such basins is to encounter extreme variance in most statistics. For example, fish assemblages are variable, and they depend upon highly variable food supplies, though many are substitutable. To detect differences in fish or fish food in a stream watershed resulting from a timber harvest or change in range management is unlikely, largely because of such pre-existing variabilities. Logging effects are largely a function of surface topography (as well as the loggers' activities). To generalize about such effects will be difficult, for it will require many streams and many years of data to account for the variations known to occur.

As we study streams, we find some that need restoration. Rural System defines restoration not as change to a historic condition, but to a condition meeting the many objectives of Rural System, i.e., temperature, sediment load, structure, biological life, oxygen level, and low toxic substance levels. Typically, these together form a standard of the quality of faunal space for game fish, but within Rural System, we create and market a *spectrum* of potential stream benefits and services.

More generally, we seek fairly natural or primitive conditions and a rich stream fish community. We expect high variance in fish richness and abundance within stream reaches. We therefore continue to study and seek to express precisely the objectives related to stream restoration, subsequent stability, and productivity of many benefits. While scientific foundations are needed for decisions, there are other dimensions of accumulated experience, as well as anticipated financial gains, that need to be articulated in plans and project descriptions.

We propose providing analyses of the economics of stream ownership and restoration for owners. We shall provide a monetary estimate to both gross financial gains from stream and riparian stabilization, and especially an estimate of financial losses mitigated, influencing *net* gains.

Many forest streams provide esthetic benefits and increase land value. How forests are managed can influence forest streams and thereby influence:

- water quality (and costs of cleanup);
- groundwater levels;
- riparian (shoreline) vegetation;
- fishing quality;
- many related bird, mammal, amphibian, and insect populations;

- many wildflower and other plant species; and
- sediment collecting at the mouth of rivers of the region.

Forests contribute to the organic matter in streams, thus to the food of insects, crayfish, and other creatures, as well as to the fish that feed on them. The bark, twigs, leaves, etc. that fall into streams contribute 70-80% of the food energy of these creatures within the water. The volumes of insects falling into the water from overhead vegetation are even more important to the fish than the insects living within the water.

Vegetation over streams, particularly that providing shade between 10 AM and 2 PM, is critical in regulating stream temperature. Trout require cool temperatures; other species require warm water.

Forests, when well-managed, can reduce sediment in streams. Particularly hard on some organisms, sediment fills in pools (critical habitat for large fish), and buries spawning and feeding surfaces. When sediment loads in streams increase, streams become wider, have less shade, and water temperature increases. In the stream, as elsewhere in the forest ecosystem, one change usually produces several other changes. Stream sediment, as little as 17 parts per million, can have harmful effects on fish in streams. Any improvement in reducing stream sediment will probably increase the life in the stream. Bridges, crossings, culverts, and interior road ditches can be very harmful in producing silt.

Streams in the mountains are complex and diverse, strongly influenced by large wood that is within them or at the edges. Large wood creates pools, stores inorganic sediments and organic matter, and creates a stepped channel profile or gradient. Wood causes abrupt and persistent changes in channel patterns and positions, and is the major structural element responsible for backwater and side-channel formation.

Large wood maintains spaces for fish by altering the stream velocity, providing volumes where fish may feed and trapping biological matter, giving many organisms an opportunity to feed on or otherwise process it. Wood also provides protection to some forms from predators, shelter during high winter and spring flows, and an important attachment and feeding surface for invertebrate animals.

By placing large wood and boulders in streams, channels can begin recovery and fish populations along with them. Streams need to be "stair-stepped" with rocks, large logs, and tree limbs to reduce water velocities, reduce scouring, and to form and maintain pools.

Landowners who preserve forests are therefore also potential fish habitat and groundwater managers. By making small streams stair-stepped, forest owners increase groundwater recharge and (most importantly) reduce channel cutting or the depth of small valleys. The lower the stream, the lower the groundwater. The lower the groundwater, the lower the forest site index, a measure of how productive a site may be for tree growth. We might count the large pieces of wood along a 1,000m stream reach (or reaches) and find, e.g., 210 pieces. After 10 years and stream restoration, the count along the same stretch might be 2,200. Comparisons of fish numbers in the same stretch might show increases over the baseline condition.

There are many studies performed and within our files. Many of those are rich with descriptors (e.g., channel-as-pool; stream order) and need to be used consistently to develop, within VNodal, a current, changing, and probable picture of each stream, related populations, and their financial derivatives… to achieve (then protect) its full resource potential within the next 40 years.

I have emphasized cold-water streams and their fishery in this section. Equivalent and over-reaching emphasis is suggested for the farm-pond fishery, typically of warm-water species of fish. Stocking fish in warm-water streams is not recommended, since most streams, under normal circumstances, will be supporting the population that it is capable of maintaining, unless conditions in the steam have been altered recently. If the stream is near its carrying capacity, the newly stocked fish could upset the delicate natural "balance" between predator and prey species. This could cause a reduction in prey species which, in turn, would result in the reduction of predator species to a level below that which existed prior to stocking. Stream fish populations also tend to move within a stream. A fish released at one point might not set up population abundance until it has moved several miles, upstream or downstream, from the point of stocking.

The Rural System Pond Fishery: Angling for Profits

The farm pond is only one part of a complex rural fishery, and that exists within a complex pond cluster and small-lake aquatic resource presence—our local **hydro-system**. We use the phrase *hydro-system* to designate (for local use and ease of discussion) our on-going linkages of:

- Ponds with streams;
- Streams with headwaters phenomena;
- Headwaters with Crescent-Area boundaries;
- Crescent-Area concepts with conventional watersheds;
- Watersheds with interior “permanent” wet areas (seeps, etc.);
- Seeps with riparian zones and volumes;
- Riparian volumes with small nearby water sources (pipes, channels);
- On-site water sources with transported groundwater and others;
- Other imported waters with all types of precipitation sources; and
- Deep waters with fish and other aquatic organisms.

Rural System’s hydro-system concept is complex, encompassing everything water-related, including ice and fauna relations. The hydro-system is large, diverse, seasonal, and variable. We design and shall use a comprehensive means for rapidly and reasonably analyzing rural ponds, then to use those analyses to build a lasting human food supply of fish for regional populations, along with clean water, jobs, and recreational resources.

The work of **The Fishery Group** is part of an integrated plan for a large number of existing ponds on enterprise environments to be managed together, as part of a regional fishery. This Fishery Group has separate, first-order start-up potential, unlike the clusters of interactive work needed for many other planned Groups. We shall work toward an integrated program, fully aware of the enormous number and diverse scale of factors affecting our pond-portion of the potential regional fishery, i.e., air and water quality, climate temperature, soil management, pollution prevention, wild fauna and flora, treatment of each “catch,” and human resource uses within and around each pond.

The pond, a distinctive part of the rural setting, is capable of serving many functions and providing many benefits to owners and other citizens. We know that hundreds of ponds have been built throughout Virginia and continue to serve many roles and provide many benefits. However, we have learned from conversations with owners and personal observations that the ponds change in importance to owners, and change physically, ecologically, and economically over time. We have accumulated a large library and seek knowledge of many aspects of ponds to reduce the disadvantages, costs, wastes, and to increase the benefits and noteworthy profits as part of Rural System objectives.

Ponds, seemingly similar, are each unique. Often the landowners' objectives, as a set, are also unique, and when combined, can create a truly unique entity within a region. One strategy of pond management is to ignore the unique qualities to achieve economies of scale, and *cluster* ponds together (conceptually, if not physically) in size, shape, public information, marketing water qualities, access, desired harvests or benefits, and proposed uses.

The Fishery Group analyses will begin with gathering physical descriptions for GIS-mapped county-locations, followed by detailed, computer-filed characteristics and understanding of each pond and the factors and processes affecting them, individually and in clusters—especially the fish biota, and their numbers and weights within them. The ponds, when managed in clusters, will each be recognized as related, but each will be treated as very special or unique for particular customer bases (e.g., winter ice-skating).

In 2016, eight authors suggested an action framework of four items for profitable pond management:[11]

1. Establish a water quality objective;
2. Quantify the difference between the present condition and that objective;
3. Assess the catchment sensitivity to change (as from Crescent or watershed activity—the balance between watershed and pond or catchment basin); and
4. Determine when the buffering capacity of a system will eventually reach a threshold (saturation) level, i.e., "the point at which small changes in the inputs to a catchment cause a rapid change in the aquatic ecosystem."

We propose to develop an operational system for rapid field analysis of a series of basin analyses to provide timely, on-site analyses of pond conditions related to fish habitat suitability, as well as that of other flora and fauna. The buffering capacity determined for the pond will determine the likelihood of achieving/exceeding the target of soluble phosphorus from landscape changes (cultivation, etc.). Our pond analysis system (PAS) will be a special, profit-oriented, pond-specific enterprise purposefully linked to water quality, and evident payoffs from an improved, intensive land use—the "farm pond" —year-around, long-lasting.

Not only for analyses of Rural System ponds and their dynamic changes, the PAS has been designed as a for-profit land-analysis unit, functional for ponds in the regions around Rural System. PAS is a planned system for precisely describing a mapped unit of land-use allocation, and preparing for investment in the potential benefits from parts of any local land ownership. It will grossly address basic Alpha Units with location, adjacency, and depth aspects. A three-acre pond, for example, has 120 such dynamic water and land "columns." Three-dimensional pictures will aid staff efforts toward forming pond clusters for diverse fish, characteristics, user preferences, access, and reliability. We know of over 500 federally-funded farm ponds in Virginia, and similar numbers exist in NC, SC, and Maryland.

In general, our working premise is that a fishery is a profitable resource enterprise for the region. Underlying our premise, fishery ponds of our target lands need intensive management to be profitable over time. Readily retrievable knowledge is now available, but must be collected

[11] Donnacha et al. 2016. Optimizing land use for the delivery of catchment ecosystem services. Front Ecol Environ. 14(6): 325–332. doi: 10.1002/fee.1296

and addressed to each pond, often and as needed. That knowledge needs to be used with feedback for pond plant productivity—basic to local fishery productivity—and needs to be further developed within the context of the stream fishery to achieve hydro-system-level economies of season, scale, and scope.

Our pond evaluations shall proceed systematically:

1) We shall compile physical descriptions (including GIS location), leading to understanding the factors and processes affecting each pond, and especially each fish population set.
2) We shall group ponds into clusters for management to reach economies of scale.
3) Next, we shall test and perfect the tools and reports about each pond for land owners and others.
4) We shall then compare ponds, and build models that unify that knowledge for predictive uses, especially for new demands for products as factors outside of ponds change.
5) We shall study and devise means to maintain and improve our present library and required knowledge base for use in models supporting prescriptions for pond-specific action.

We are statewide in orientation but focus first efforts within the Roanoke-Botetourt and Blacksburg areas, then expand westward. The "pond" scale quickly requires Crescent analyses, and these, like the ponds themselves, require Alpha Units. The *clusters* of ponds will bring in sub-regional analyses as we develop markets for anglers and others for fish-protein consumption.

We'll make cooperative-wide reports of activities and progress. Prescriptions, however, will be reserved for the Land Force use at each pond, and are somewhat proprietary. We'll summarize characteristics annually. We'll study the role of a Rural System annual report and the place within it of the ponds report. These may be seen as part of a growing knowledge base that itself may be available for use at some fee. Rural System will generate an occasional report of regional conditions that we shall infer from the ponds treated as regional samples.

We plan to employ intensive social media marketing, including YouTube videos, podcasts, and a fishery blog, and will actively explore creating mobile apps for fish products for customers of various types, as well as active angler recruitment and satisfactions. Visitors to Fishery Group ponds and pond clusters will be able to purchase fish food to scatter and view fish action. We shall seek cooperative relations with restaurants for use of our fish, and use pictures of customers enjoying fish, some of our fish on display in aquaria, and high-quality fish photos to enhance our branding. We may harvest algae for soil composting and eventual sale. After Rural System becomes stable, we'll be able to provide a membership price for year-around services within our pond clusters.

As in other enterprises of Rural System, I'll encourage branding of and enhancing recognition of our resources. In this case, the ponds themselves will be pictured and explained as enhanced by fish and fishing, and later by direct sales of processed fish, lessons for understanding them, and even cooking ideas. We shall work on the idea that people like food and experiences that come along with a story.

Only the conceptual, perhaps novel framework for the hydro-system, is sketched here for development in the near future. A diverse market can be created, with unique qualities and with productivity justified on the predicted needs for human food in the next several decades. We shall add esthetic elements of the ponds, recreational events, sporting contests, and diverse angling invitations for public sport, education, and recreation. Together we shall add an array of services (i.e., keeping fertilizers out of ponds). Rural System plans to expand the full opportunities of a model national, regional inland fishery with abundant, diverse, profit-based enterprises and social benefits.

We perceive we are in a modest type of competition with state and federal fishery resources, but we offer differences for anglers and others. We shall actively use public resources of fishery scientists and public information and resource findings (treating these as public offerings, from agencies such as the National Cooperative Extension Service—as variable and as public as history, law, libraries, histories, etc.), public awareness, volunteered assistance such as in law enforcement, and in fish stocking—general approval, sharing of objectives, and illegal action observed.

The Fishery Group of Rural System is intently and specifically involved, year-around, permanently, in directly managing a geographically-specific fishery resource—that from each cluster of ponds and streams managed by Rural System. The fishery resource will be local, dynamic, and designed to meet the needs of many people.

Our Group title, "Fishery," does not suggest our emphasis on human needs or the total system upon which living populations depend, over many unnamed years. Our interests are not trivial, but tend to be inclusive with those for the total, diverse fish-related resource, much of which is on or over private land.

We hold that we are managing to meet the abundant "fishery" benefits potentially available from that *private* resource (other than state, federal, or oceanic). We hold the resource is private when most life time of each individual of each species is typically spent involved, and dependent, upon a named, freshwater impoundment or pond, largely or wholly owned by a private land owner.

We are fully aware of the complexity of the fishery resource, and work within the fishery—*the whole system*—well-aware of its size and complexity, and our limitations. We shall be aided by an active field and laboratory staff using modern equipment and computer efficiencies, well-planned action, and full response to the demands of "a systems approach" to a large, complex, evolving private-land-based natural resource: The Rural System Fishery. We plan to implement well that complex fishery, year-around, for bounded profit for at least the next 150 years, sliding forward a year, annually.

Water: Specific to General

We know of "water pollution," but not everyone knows of "non-point sources." Rainfall or snowmelt from suburban lawns, golf courses, and paved surfaces pick up and carry away natural and human-made pollutants, depositing them into lakes, rivers, wetlands, coastal waters, and ground waters. Roads, parking lots, sidewalks, homes, and offices now replace natural landscapes. Rainfall that once soaked into vegetated ground now becomes "storm-water runoff," which flows directly into local waterways (where some fish may remain).

As more natural landscapes are converted to impermeable surfaces or managed turf, storm-water moves across them. We need to stop pollutants, especially non-point sources such as sediment and nutrients, to vulnerable streams and, for example, the Chesapeake Bay. Storm drains on street corners need to provide water filtration. We now must exert efforts to retroactively address storm-water runoff from existing impervious surfaces, and address how to stop destroying water quality.

Will we be able to obtain more fresh water? Yes, gained at high costs by modern technology; or in Virginia, for example, it will be moved cross-country from mountains' rainfall to coastal beaches, for dense urban uses, and there packaged for energy-costly return trips, to Central and Northern Virginia. The coastal cities have inadequate supplies of fresh water, and high demand for water now abundant in the mountains.

Discussions and conversations about water bring phrases like "our beaches," "our coastline," "our clean water is going where?" and "…says who?" Then emerge pious thoughts about unified regions, state conglomerations, and 190 or more countries of the United Nations. I begin to wonder if water rights and solutions therein might *ever* be resolved, or those of Virginia, or those of the range-lands of Western United States where water was scarce even within movies of yesteryear!

Rural System successors will, as have farmers and developers of all similar lands and waters, encounter public and legal dimensions unimagined… but ever-present. My optimism for people of the rural future resides in current databases and knowledge of the Earth—now as never known or realized before. People can now see the dynamic part of the world in which they live, their adjacencies above and below, as well as mapped edges, and zones for seemingly inevitable conflict.

As never before, people communicate (reluctantly or not) and have GIS capabilities for seeing and working with the Earth's surface. We can move to clear, agreed boundaries and explore the wonders of the measurable benefits of family, community, coalitions, and conditional units. And now major, robust technology allows us to live within conceptual 3-dimensional Earth … it is very deep, Earth-around, and stretches far above into the atmosphere. Now, as never before, we can conceptualize this and we need not make a mess of it!

We know so much, and have opened the knowledge-book for everyone. We need not suffer now, for I believe we know enough to survive on Earth. Within 50 years, after 2050 AD, with wise investments into water system knowledge using what we know now, we may soon develop a structure for alternative advances and continued action against disease, ignorance, pollution, and multi-dimensional wastes. We may further take actions promoting/supporting multi-resource limitations and intensive management, limited human population, functional energy access, and the elements of **"Decent Work"** (Appendix 3).

In view of the year 2030 AD from here, there may be wisdom and excitement for the elderly as they study, plan, and invest for their Earth-conscious, respectful children …who have grown fearless of the presence and effects of radio-nuclide poisons in their waters.

About the Author

While many Americans are presently astonished at conditions in rural America, Robert Giles, Jr., Ph.D., has been working tirelessly for decades on planning solutions to interconnected rural problems. Dr. Giles is a Professor Emeritus of Wildlife Management at Virginia Tech where he taught for 30 years. His Bachelor of Science degree in Biology and Master of Science degree in Wildlife Management are from Virginia Tech. His Ph.D. in Zoology is from The Ohio State University.

Dr. Giles was born on May 25, 1933 in Lynchburg, Virginia. He attended E.C. Glass High School, during which he was awarded a Bausch and Lomb Science award for studies of the ring-necked pheasant. As an Eagle Scout, he was awarded the W.T. Hornaday National Award for Distinguished Service to Conservation and the James E. West Scouting Conservation Scholarship. During his undergraduate years at Virginia Tech, Dr. Giles was an editor for several magazines and the president of the V.P.I. Corps of Cadets of 6,000 students. He was also a member of seven national honorary societies.

During his time as a Professor in the Department of Fisheries and Wildlife at Virginia Tech, Dr. Giles was known for his innovative applications of computer programming and Geographic Information Systems (GIS) to land management questions well before such skills became standard practice within the field (and before GIS was a term). With the support of the Tennessee Valley Authority (TVA), he created the woodland resource management system of TVA, once used on 300 farms a year. With staff and students, he created the first wildlife information base (BOVA – Biota of Virginia database). As chairman of a local planning commission, consultant to the National Wildlife Refuge System, aid to the State Cooperation Commission, consultant for Wintergreen and several realtors, and as a landowner himself, he has developed a unique and alternative perspective on land and its management. He wrote the first plan for wildlife other-than-game for Virginia.

Dr. Giles began working on the Rural System concept in the early 1980s, but did not begin in earnest until his retirement in 1998. When asked about his aims for designing Rural System, he said, “I am now convinced that a superior demonstration of modern comprehensive natural resource management is badly needed and is now possible and most likely within the context of a new corporate rural structure. I do not want to do research. I do want demonstrations of the results of literally millions of dollars of unused research findings. I propose to bring all the power of the computer that I can to realistic and relevant use for parts of the region. This will include using that power already achieved by investments of resource agencies. I propose a system, subject to the law and to reasonable issues of cost, propriety, and community acceptance, that achieves such objectives.”

A colleague of his once said that Dr. Giles can come up with more ideas in an hour than most people can in a lifetime. His creativity is exceeded only by his humanity. Raised in Southwest Virginia, Dr. Giles knows the struggles of people in Central Appalachia, impoverished after the collapse of coal and tobacco industries. He has visited rural areas of Africa (Nigeria, Senegal, Uganda), China and India, and is well-educated in the sufferings of people in poverty worldwide.

Dr. Giles is a systems thinker. He believes that the problems faced by environmentalists and those of interest to humanitarians are interconnected, and that a system of problems must be met with a system of solutions. His career, his values, and his innovative capabilities make him uniquely suited to tell the story of how a for-profit systems approach can best solve the rural problems of a progressive, capitalist society.

Contact information:

Robert H. Giles, Jr., Ph.D.
509 Fairview Avenue
Blacksburg, Virginia 24060
United States of America

Publisher:

Handshake Media, Incorporated
http://www.handshakemediainc.com
contact@handshake20.com