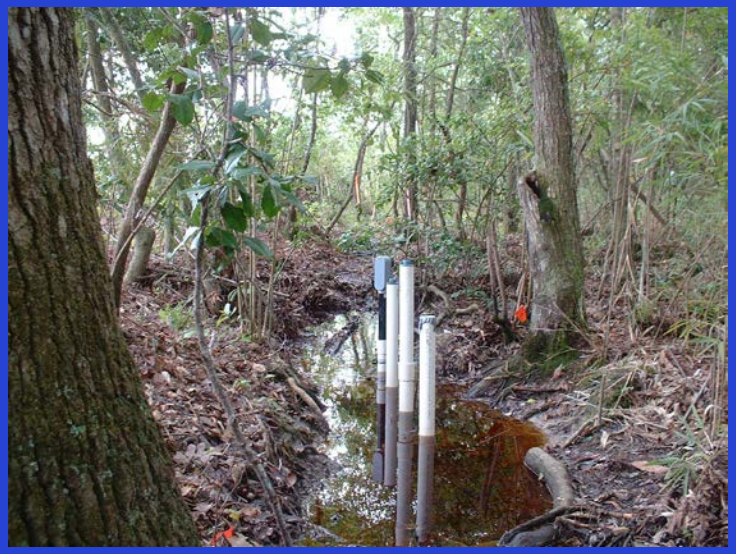
What is an appropriate reference framework for ecological assessment, restoration, and monitoring?



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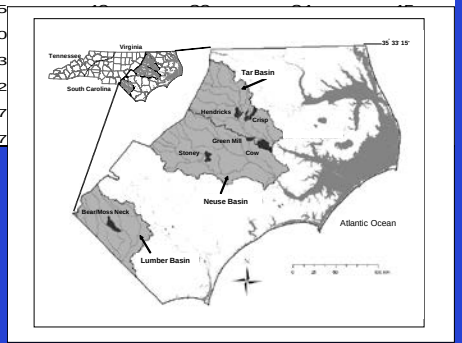
Conference on Ecological and Ecosystem Restoration
New Orleans, LA, July 28- August 1, 2014

Applications

Watershed	Riparian zone cover (RZC)	Near-stream cover (NSC)	Instream woody structure (IWS)	Sediment regime (SR)	Channel-riparian zone connection (CRZC)	Pollution affecting stream (PAS)	Factors affecting riparian zone (FARZ)	Habitat quality of riparian zone (HQRZ)	Stream bank stability (SBS)
Cow	38	41	45	31	25				
Crisp	31	37	44	32	10				
Green Mill	71	79	66	33	43				
Hendricks	64	73	61	57	62				
Stoney	70	72	66	51	67				
Lumber	43	47	55	30	37				



Watershed Planning

Framework: Preliminary considerations

- How will it be used? (Assessment, monitoring?)
- Target ecosystem?
- For what region?
- Who will use it?
- What level of training will be required?
- Will it use check lists, narratives, field metrics?
- How rapid must it be?
- Will it measure condition, functioning, or both?

Common attributes of a successful reference framework

1. Differentiate between natural (noise) and human-caused (signal) variation

The Good,

the Bad,

and the Ugly.

2. Identify environmental stresses

3. Quantify condition or functioning using reference data

HGM Approach (Logic Equation Framework)

Function: **Maintain Characteristic Plant Community**
(for headwater floodplains)

$$FCI = \left\{ V_{HYDROALT} \left[\frac{\frac{(V_{BIG3} + V_{TDEN})}{2} + V_{COMP}}{2} \right] \right\}^{1/2}$$

$V_{HYDROALT}$ = degree of hydrologic disconnect between floodplain and stream

V_{BIG3} = mean diameter of 3 largest trees in 3 plots (n=9)

V_{TDEN} = density of trees > 15 cm dbh

V_{COMP} = composition of trees > 15 cm dbh

EPA Wadeable steams (Narrative framework)

Parameters to be evaluated in sampling reach

Habitat Parameter	Condition Category			
	Optimal	Suboptimal	Marginal	Poor
1. Epifaunal Substrate/ Available Cover	Greater than 70% of substrate favorable for epifaunal colonization and fish cover; mix of snags, submerged logs, undercut banks, cobble or other stable habitat and at stage to allow full colonization potential (i.e., logs/snags that are not new fall and not transient).	40-70% mix of stable habitat; well-suited for full colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of newfall, but not yet prepared for colonization (may rate at high end of scale).	20-40% mix of stable habitat; habitat availability less than desirable; substrate frequently disturbed or removed.	Less than 20% stable habitat; lack of habitat is obvious; substrate unstable or lacking.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
2. Embeddedness	Gravel, cobble, and boulder particles are 0-25% surrounded by fine sediment. Layering of cobble provides diversity of niche space.	Gravel, cobble, and boulder particles are 25-50% surrounded by fine sediment.	Gravel, cobble, and boulder particles are 50-75% surrounded by fine sediment.	Gravel, cobble, and boulder particles are more than 75% surrounded by fine sediment.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
3. Velocity/Depth Regime	All four velocity/depth regimes present (slow-deep, slow-shallow, fast-deep, fast-shallow). (Slow is < 0.3 m/s, deep is > 0.5 m.)	Only 3 of the 4 regimes present (if fast-shallow is missing, score lower than if missing other regimes).	Only 2 of the 4 habitat regimes present (if fast-shallow or slow-shallow are missing, score low).	Dominated by 1 velocity/ depth regime (usually slow-deep).
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
4. Sediment Deposition	Little or no enlargement of islands or point bars and less than 5% of the bottom affected by sediment deposition.	Some new increase in bar formation, mostly from gravel, sand or fine sediment; 5-30% of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, sand or fine sediment on old and new bars; 30-50% of the bottom affected; sediment deposits at obstructions, constrictions, and bends; moderate deposition of pools prevalent.	Heavy deposits of fine material, increased bar development; more than 50% of the bottom changing frequently; pools almost absent due to substantial sediment deposition.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
5. Channel Flow Status	Water reaches base of both lower banks, and minimal amount of channel substrate is exposed.	Water fills >75% of the available channel; or <25% of channel substrate is exposed.	Water fills 25-75% of the available channel, and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

4. *Identify potential constraints to recovery*

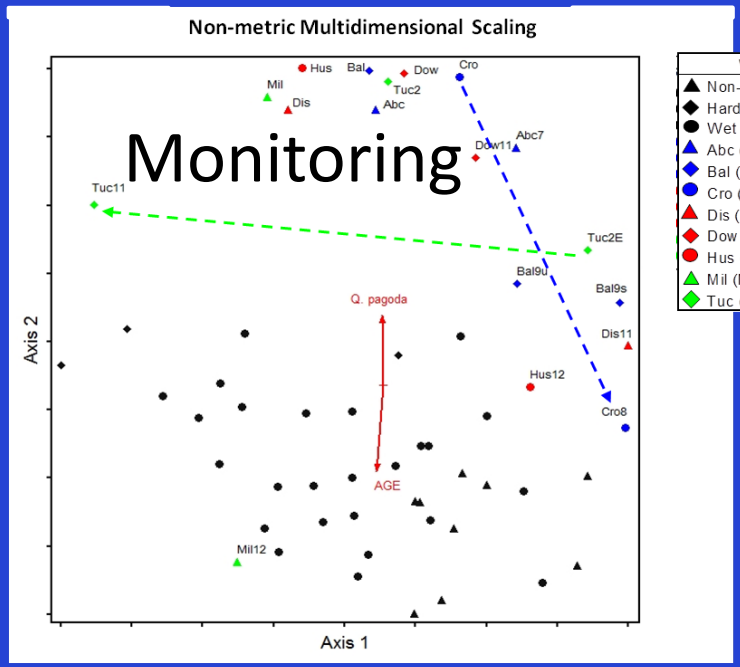
(Applicable to restoration only)

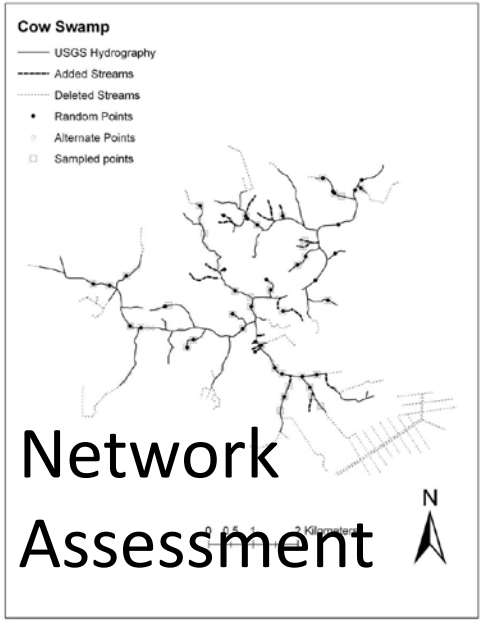
- Surrounding landuse/land cover, watershed condition
- Proximity of invasive species

5. Identify a reasonable final target or intermediate target conditions

?

Applications





Example 1: Salt marsh restoration:

Stress: trampling
Condition: area of bare soil
Constraints: continued use
Target: substantial increase in marsh cover

BRACKEN ENGINEERING, INC.
MEAN HIGH WATER (el. 2.24)
per MONUMENT BEACH TIDAL STATION
PROPOSED ' WIDE BOARDWALK
2.24
2.24
2.24
2.24
2.24
2.24
(0)
(0)
(0)
(0)
(0)

Example 2: Rapid assessment protocol for headwater ecosystems in an agricultural landscape

Stresses: channelization, poor buffers

Constraints: LULC (active farming), roadside ditches

Variation: channelized, deforested buffer zones to natural streams with intact, mature buffers

Condition: score 0-100 (worst to best)

20.0 km
Image Landsat
Google

Framework to measure condition at the scale of a defined reach (e.g., 100-m)

		Degree of Alteration			
		Good	**Not Bad**	**Bad**	**Ugly**
		HIGH ← CONDITION → LOW			
Condition Categories	**Dominant LULC of watershed**	Mature forest or agriculture with BMPs	Agriculture with or without BMPs	Agriculture	Agriculture
	Stream Channel	Natural or restored channel	Natural or slightly incised, channel	Incised or channelized, but not maintained	Channelized, maintained or deeply incised
	Riparian zone	Mature forest buffer	Young forest buffer	Narrow forest buffer of trees and shrubs	No woody vegetated buffer

Narrative approach

- *Detailed description of indicators (n=6)*
- *Similar to EPA Wadeable stream survey (0-20 scale)*
- *Scale= 0-100*

Condition Indicator	Condition Category			
	Relatively Unaltered	**Somewhat Altered**	**Altered**	**Severely Altered**
1. Instream woody structure (detritus)	**(a)** Several pieces of large downed wood (LDW) are within the channel and along banks, representing a mix of sizes 4 to >15 inches (10-40+ cm) in dia. and decay classes. (Recent treefalls from extreme weather events not applicable.) BUT **(b)**, for streams channels that are dry for long periods, tree roots with hypertrophied lenticels are located at channel surface; large roots in channel create small pools that trap leaf litter when available.	**(a)** LDW sparse and/or small in size (few or none >4 inches dia.) or not representing a variety of decay classes. BUT **(b)** For streams channels that are dry for long periods, tree roots located in stream bottom lack hypertrophied lenticels; few or no large tree roots present in channel capable of creating small pools that could trap leaf litter.	**(a)** No LDW or LDW represents only one decay class deposited during an extreme storm event; channel frequently de-snagged[1]. BUT **(b)** For stream channels that are dry for long periods, and channel has been channelized, it is maintained so infrequently that small trees or shrubs grow in and/or along channel.	Stream is channelized, lined with rocks, or has been frequently excavated or cleared of debris to maintain drainage. [Lowest score should be given to channels that are lined with rocks.]
Score =	100 90	80 70 60	50 40 30	20 10 0

Assessment using a narrative framework

Indicators

Instream woody structure

Sediment Regime

Channel-riparian zone connection

Factors affecting stream

Factors affecting riparian zone

Habitat quality

Narrative

Condition Indicator	Condition Category											
	Relatively Unaltered		Somewhat Altered			Altered			Severely Altered			
1. Instream woody structure	Much large down wood (LDW) in channel and along banks. (Recent treefalls from extreme weather events or erosion not applicable.) (a) LDW represents a mix of d[illegible] classes[1]. (b) LDW in channel and along banks represents a mix of sizes >4 inch dia.[2]. Some LDW > 8 inch dia. (c) For stream channels that are dry for long periods, tree roots with hypertrophied lenticels are located in stream bottom (d) Large (>1 inch) tree roots in channel create small pools that trap leaf litter, when available.		Some LDW in channel and along banks, some may be partially buried in bottom. (a) LDW in channel and along banks [illegible] (b) Few or no LDW > 8 inch dia. [If large >4 inch dbh trees grow along both banks, score 80, if only along one side, score 70, if streamside trees are <4-inch dbh, score 60.] (c) For streams channels that are dry for long periods, tree roots located in stream bottom lack hypertrophied lenticels			Few or no LDW in channel and on banks[2] but potential supply is present. (a) LDW represents only one decay [illegible] stream channels that are dry for long periods, channel is maintained so infrequently that small trees or shrubs grow along channel banks. [If large >4 inch dbh trees grow along both banks, score 50, if only along one side, score 40, if streamside trees are <4 inch dbh, score 30.]			No LDW in channel (a) Stream is channelized or deeply incised and periodically cleared of debris to maintain drainage [illegible] along channel banks. (c) Stream is lined with rocks, rip-r[illegible] concrete. [Lowest score should be given to trapezoidal channels with concrete bottoms.]			
Score =	100	90	80	70	60	50	40	30	20	10	0	
2. Sediment regime[3]	Water runs fairly clear even during periods of high flow. (If originating in flats, water is may be dark (tea colored) due to tannins.) (a) Stream is not channelized. (b) Channel bottom is mostly sandy or clayey with little or no silt on channel bottom or on floodplain. [If sand deposition in channel bottom is due to upstream activities, then see "severely altered" category.]		Some silt carried by stream. (a) At high flows, suspended sediment evident in water. (b) When water runs clear during base flow, sediment[4] can be re-suspended by shuffling feet in channel. (c) Thin layer (<1 inch thick) of silt deposited on channel bars or on floodplain surface. [Thickest deposits score lower.] (d) Sediment <1 inch thick due to recent abandonment of impoundment.			Silt and sand carried by stream. (a) Water is silt laden, esp. after heavy rains. (b) Thick (1-2 inches) silt or sand deposited on channel bars, bank edge, or on floodplain (if present). (c) For streams that are dry for long periods, sand or silt may collect behind root dams and be deposited on floodplain (if stream not channelized or incised).			(Heavy sediment load carried by stream. (a) Sediment suspended in wate[illegible] during low flow. (b) Thick (>2 inch) sand or silt layers recently deposited on channel bars, bank edge, or on floodplain (if present). (c) Evidence that sand or silt deposits in reach are being generated by upstream activities. [Sand or silt on an artificial stone bottom scores lowest.]			
Score =	100	90	80	70	60	50	40	30	20	10	0	
3. Channel-riparian zone connection[5]	Strong evidence of overbank flow on floodplain. (a) No apparent channelization or incision. (b) Wrack, sediment, and/or trash on floodplain. [Sparse wrack scores 45.] (c) High water marks on trees apparent. (d) No spoil berm alongside channel.		Evidence of occasional overbank flow on floodplain. (a) Some wrack, sediment, trash on floodplain, but sparse and/or old. (b) Stream channelized within historic channel with low spoil berms or breaks in them along channel. (Channel may have been channelized in past, but is filled with sediments to such a degree that overbank flow now occurs.) (c) Channel slightly channelized or incised.			Evidence of overbank flow only after extreme (rare) flood events. (a) No or little wrack on floodplain. (b) Channelization (i.e., spoil berms present and high)[5]. (c) Channel deeply incised (not channelized).			Overbank flow eliminated. (a) Deep channelization with spoil berms present[5]. (b) Filling and/or leveling of floodplain, some or all of fill may have been derived from spoil from channelization. (c) On low order streams in agricultural fields, spoil and other material spread over the historic floodplain, entirely covering it. (d) Presence of high artificial levee o[illegible] other channel-containment structure.			
Score (L) =	Left Bank:	50	45	40	35	30	25	20	15	10	5	0
Score (R) =	Right Bank:	50	45	40	35	30	25	20	15	10	5	0

E. Stream and Riparian Condition (cont.)

Condition Indicator	Condition Category											
	Relatively Unaltered		Somewhat Altered			Altered			Severely Altered			
4. Factors affecting the stream	No on-site or off-site pollution[1] affecting stream. (a) There is no pollution entering directly into the stream within the reach or within 200 yd (600 ft) located upstream from reach. (b) No livestock access to channel or waste dumping from confined animal operations (CAO) located upstream from reach. (c) Stream is not channelized.		Only off-site pollution[1] affects stream. (a) Pollution feeds directly into stream channel within 200 yd (600 ft) upstream from reach (not within reach). (b) Water from roadside ditches enters stream within 200 yd (600 ft) above reach. [More sources or more proximate pollution sources should be scored lower.]			On-site pollution[1] affects stream. (a) Water from roadside ditch directly empties into reach. (b) Overland-flow from agricultural field directly enters reach. [Field edges closer than 10 ft scores 30, 10-50 ft scores 40, >50 ft or depressed, grassy swale (BMP) scores 50.			Especially egregious pollution affects stream. (a) Pollution from confined animal [illegible] (b) Pollution from septic or sewage treatment systems entering directly into channel. (c) Livestock have access to stream within reach. (d) Sediment input from construction activities entering directly into channel.			
Score =	100	90	80	70	60	50	40	30	20	10	0	
5. Factors affecting the riparian zone (0-50 ft zone)	No factors affecting riparian zone condition within reach. (a) Stream is not channelized. (b) No pollution[1] empties into riparian zone. (c) Livestock do not have access to riparian zone. [Presence of trash or organic waste (clippings, etc.) score 45.]		Factors somewhat affecting riparian zone. (a) Stream is not channelized. (b) Some pollution[1] empties into riparian zone, but only at outer fringes (furthest from channel). (c) EXCEPT: If stream is channelized, drainage is discharged (or diverted) to riparian zone where it is detained and processed before entering stream. (d) If livestock are present, trampling and browsing are evident over <5% of riparian zone.			Factors affecting riparian zone. (a) Stream not channelized and pollution[1] enters directly into riparian zone of reach. (b) Stream is channelized, but no stormwater is diverted to riparian zone. (c) 5-25% of riparian zone (0-50 ft) of reach filled, graded, cultivated, or covered with impervious surface. (d) Livestock have access to riparian zone. [5-25% grazed and trampled scores 25, 25-75% scores 20, 75-100% scores 15.] [Presence of more categories or greater intensities score lower.]			Especially egregious factors affecting riparian zone. (a) More than 25% of riparian zone of reach graded, filled, cultivated, or covered with impervious surface. (b) Septic or sewer system leaking into riparian zone. (c) Discharge from lagoons of confined animal operations discharge directly into riparian zone. [Lack of forest in riparian zone scores lower.]			
Score (L) =	Left Bank:	50	45	40	35	30	25	20	15	10	5	0
Score (R) =	Right Bank:	50	45	40	35	30	25	20	15	10	5	0
6. Habitat quality of riparian zone (0-50 ft)	Habitat quality intact. Riparian zone dominated by old or mature native forest (>95% of area) with all strata[2] intact. No or low cover of exotic or invasive species. No grazing, mowing, or selective harvesting within riparian zone. [Old or Mature forest (>50 yr. old) scores 50; slightly younger forest scores 45. Exotics in 5-25% in any stratum scores 45.]		Habitat quality somewhat degraded. (a) Forest (with all strata[2] intact) covers 75-95% of riparian zone with remainder of area representing other cover types. OR (b) Forest (all strata intact) covers >95% of riparian zone with exotic or aggressive species covering >25% in at least one stratum. OR (c) Forest canopy covers >95% of riparian zone with at least one understory stratum of native vegeta[illegible] repres[illegible] removal or timber harvesting, etc.). [Old or Mature forest (>50 yr. old) should be scored higher than younger forests.]			Habitat quality degraded. (a) Forest (with all strata[2] intact) covers 50-75% of riparian zone with remainder of area representing other cover types. OR (b) Forest (all strata intact) covers 75-95% of riparian zone with exotic or aggressive species covering >25% in at least one stratum. OR (c) Forest canopy covers 75-95% of riparian zone with at least one understory stratum of native vegetation [illegible] harvesting, etc.). [Old or Mature forest (>50 yr. old) should be scored higher than younger forests in all cases.]			Habitat quality extremely degraded. (a) Forest covers <50% of riparian zone with remainder of area representing other cover types. OR (b) Forest (all strata intact[2]) covers 50-75% of riparian zone with exotic or aggressive species covering >25% in at least one stratum. OR (c) Forest canopy covers 50-75% of riparian zone with at least one understory stratum of native vegetation absent or not well [illegible] [Old or Mature forest (>50 yr. old) covering more than 25% of riparian zone should be scored 10; younger forest or lower forest cover scores 5, lack of trees scores 0.]			
Score (L) =	Left Bank:	50	45	40	35	30	25	20	15	10	5	0
Score (R) =	Right Bank:	50	45	40	35	30	25	20	15	10	5	0

Condition

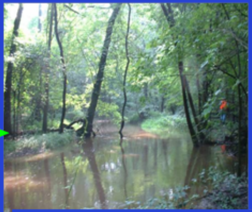
Relatively Unaltered

Severely Altered

Severely Altered

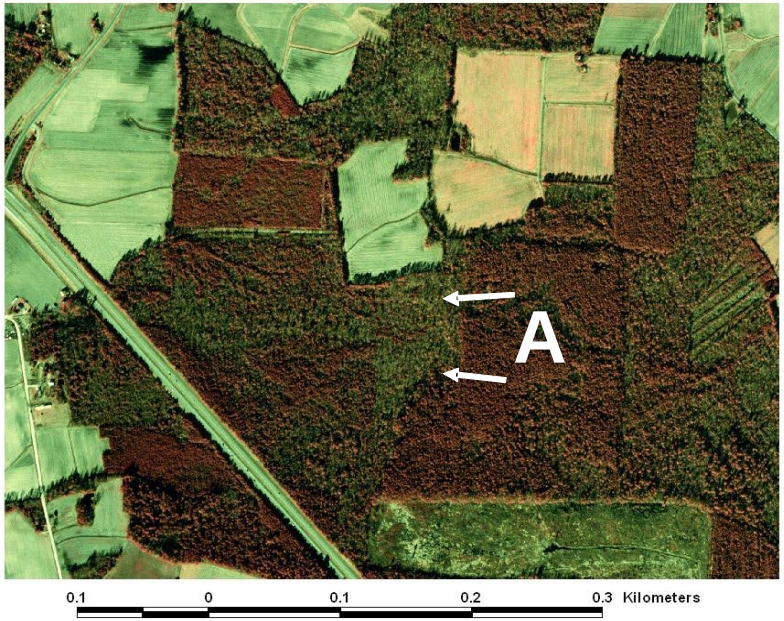
Altered

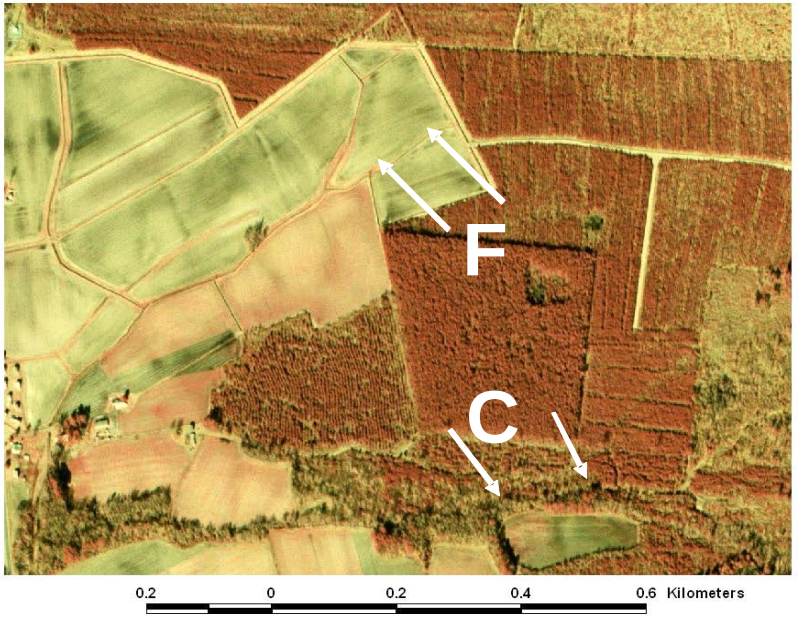
Severely Altered



Relatively Unaltered

Develop and test with field data





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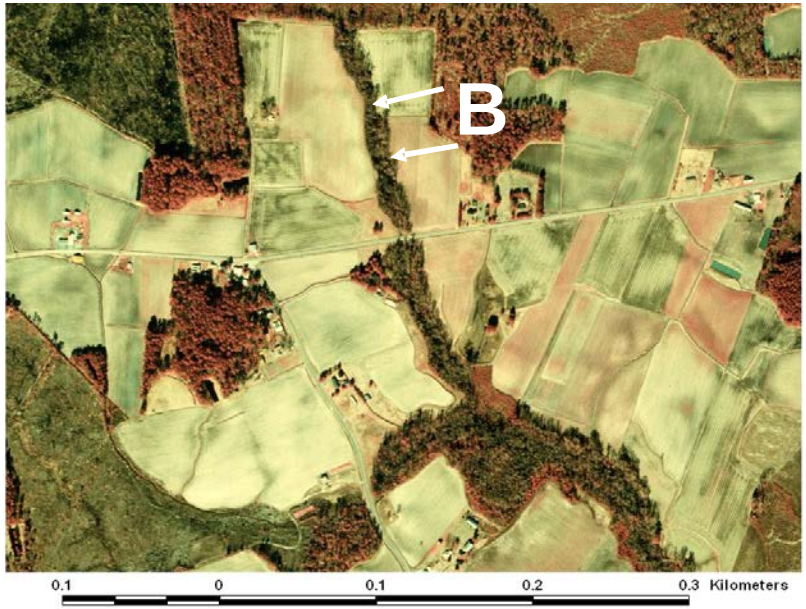
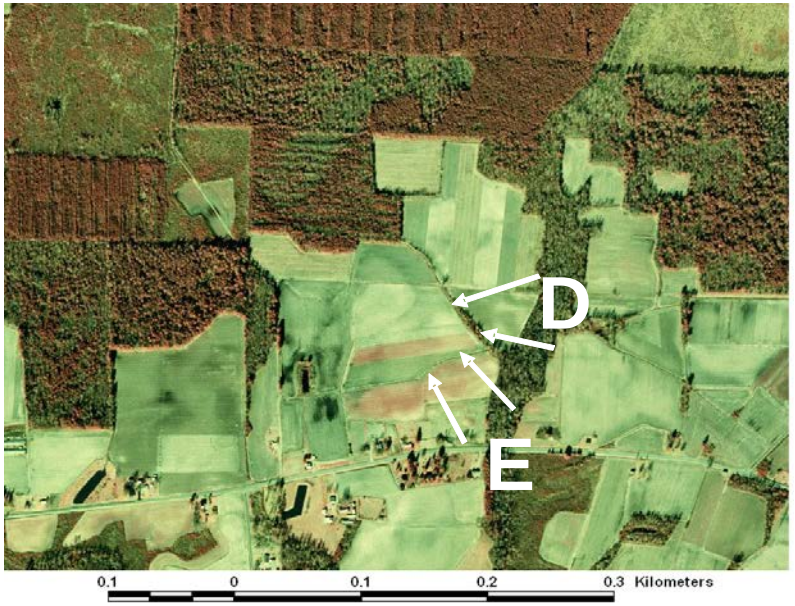
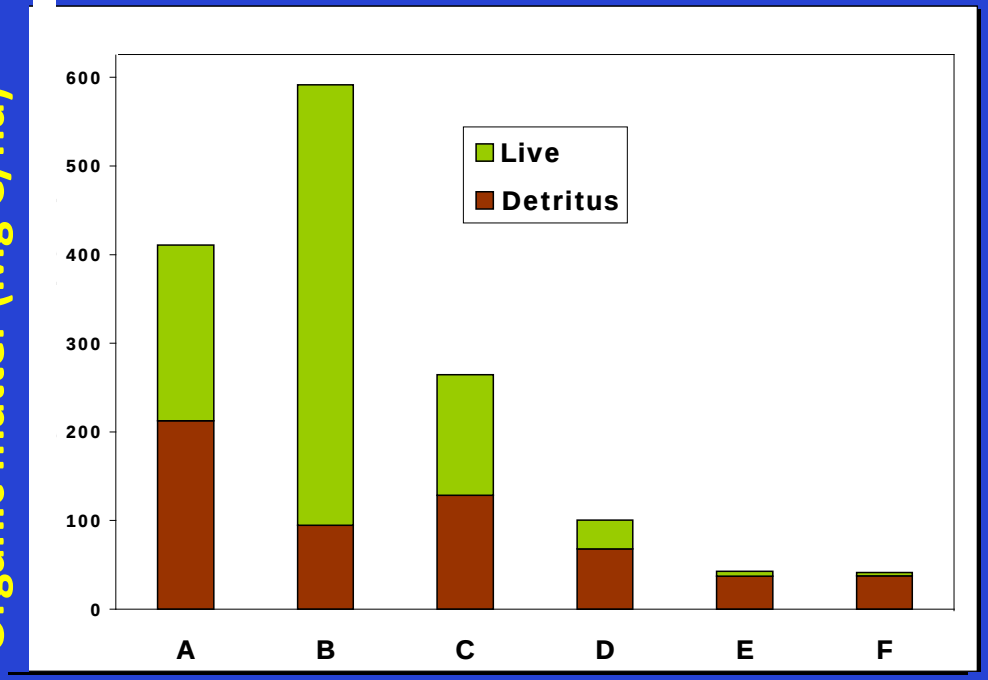




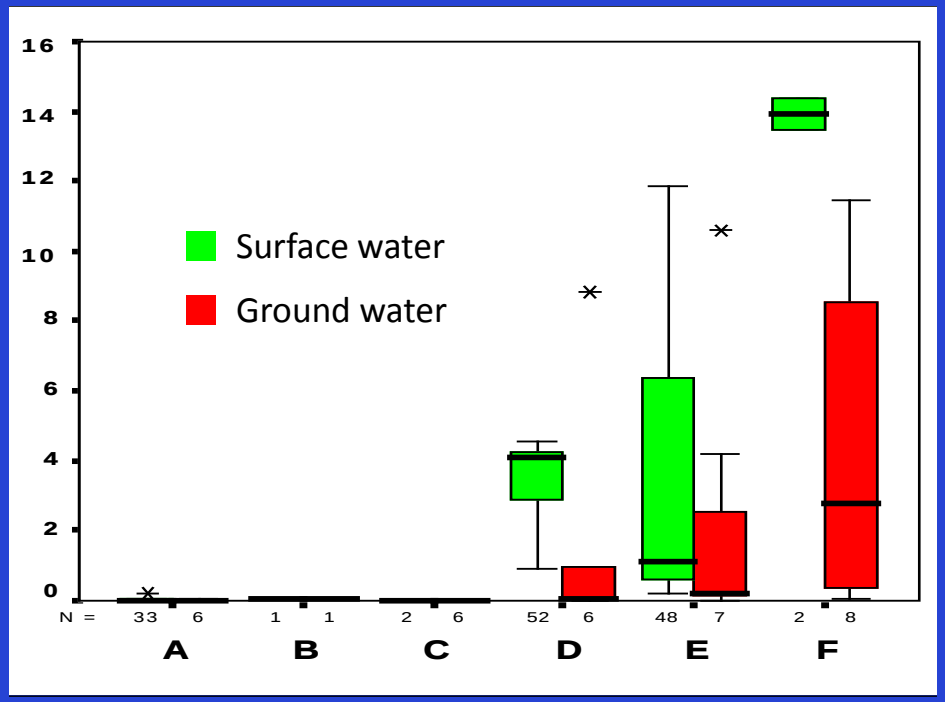


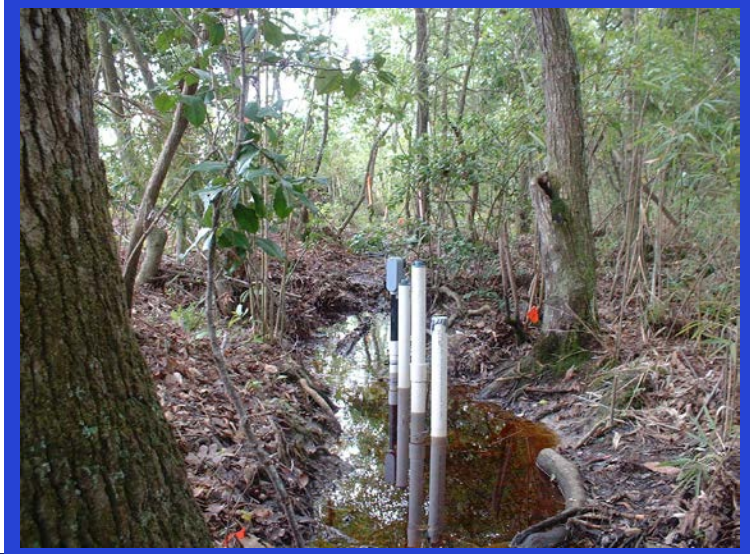
Biomass
(except roots)

vs.

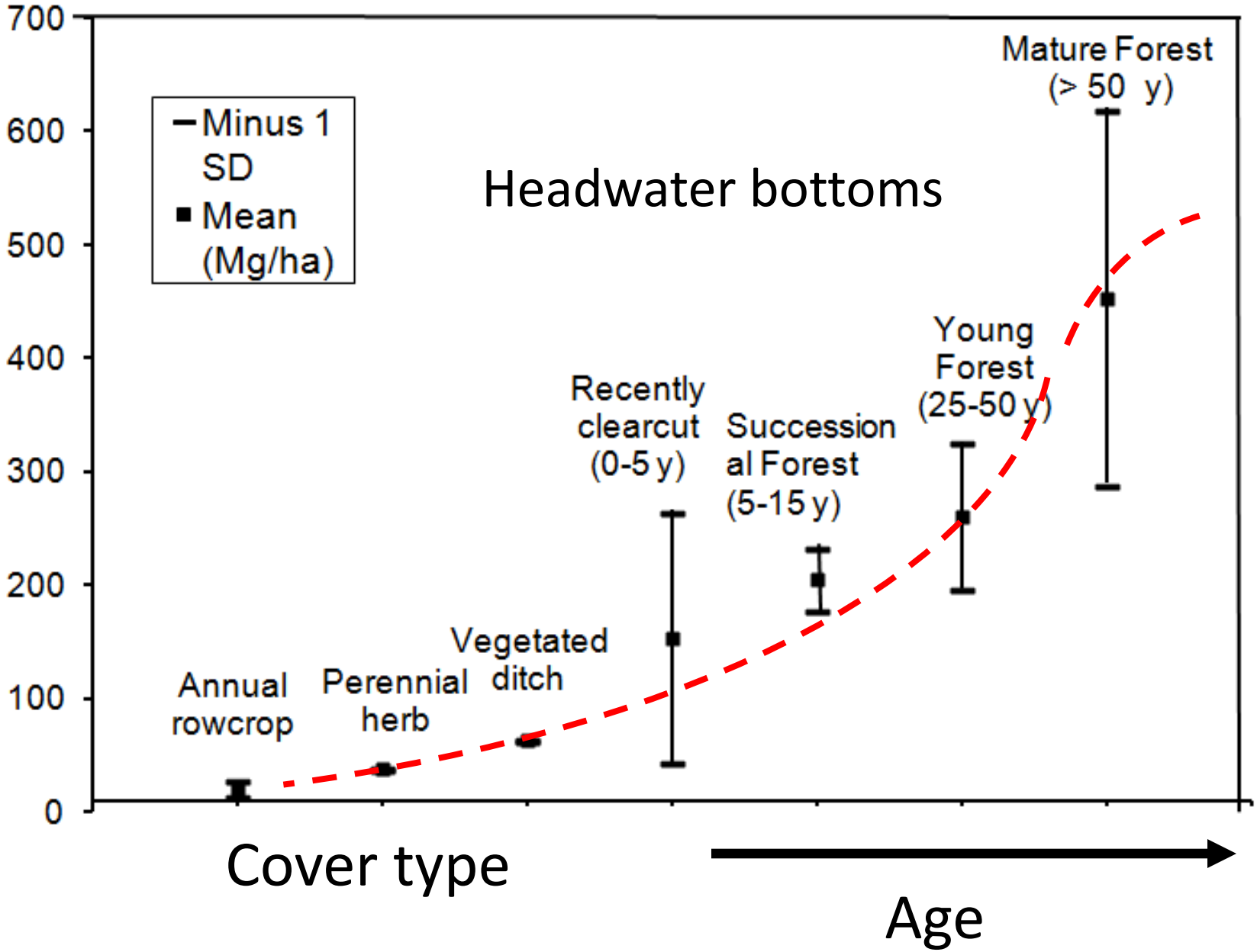
Nitrogen

(NO_3 and NO_2 from 1-yr of baseflow and stormflow data)





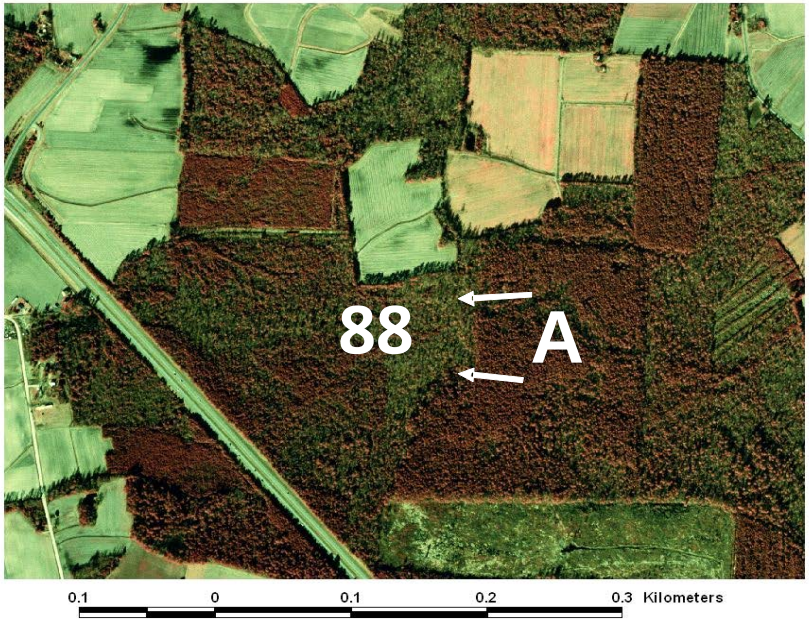
Age vs. Biomass (except roots)

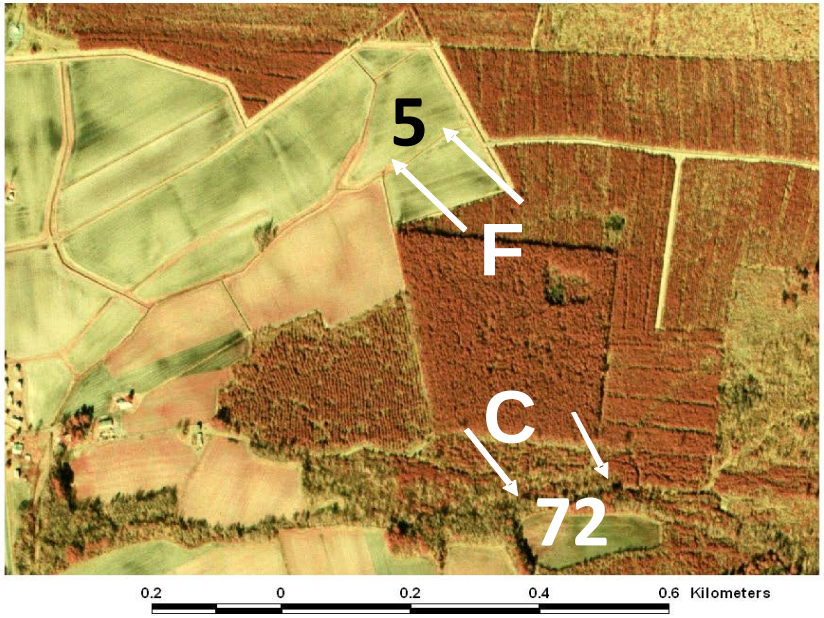


Calibrate indicator (Riparian condition)

Cover type	Age Midpoint	Biomass (MgC/ha)	Derived Biomass Index	RIGHT SIDE ZONES (distance from stream)		
				0-3 m	3-15 m	15-30 m
Old Forest	85.0	440	**1.00**	20	25	5
Mature Forest	62.5	375	0.85	(17)	21	4
Young Forest	37.5	275	0.63	13	(16)	3
Successional Forest	15.0	160	0.36	7	9	2
Recently Harvested	2.5	70	0.16	3	4	1
Shrubs/Saplings	NA	63	0.14	3	3	1
Perennial Herb (incl. residential lawns)	NA	38	0.08	2	2	0
Annual Rowcrop	NA	20	0.08	1	1	(0)
Impervious	NA	0	0.00	0	0	0
			Zone Score (column):	17	16	0
			Total Score (biogeochemical indicator):			**33**

Riparian condition score (max = 100)





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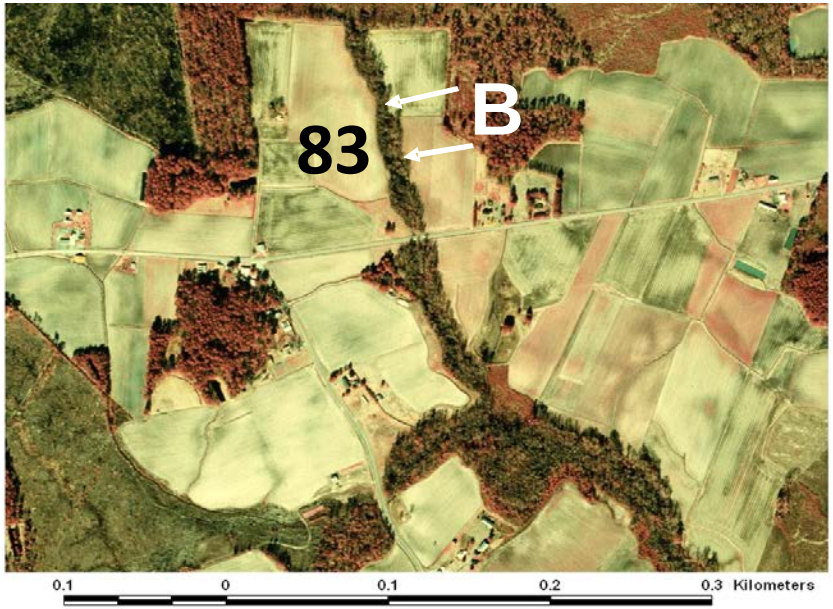
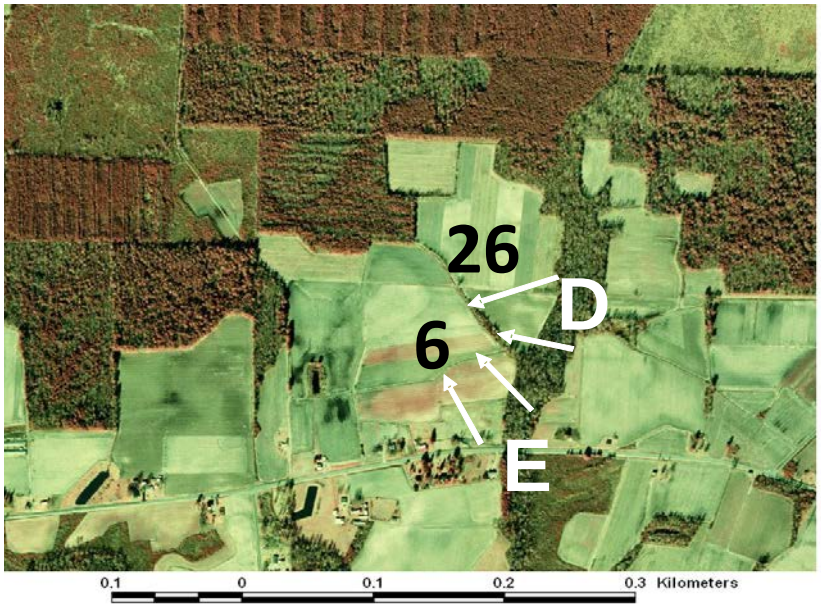
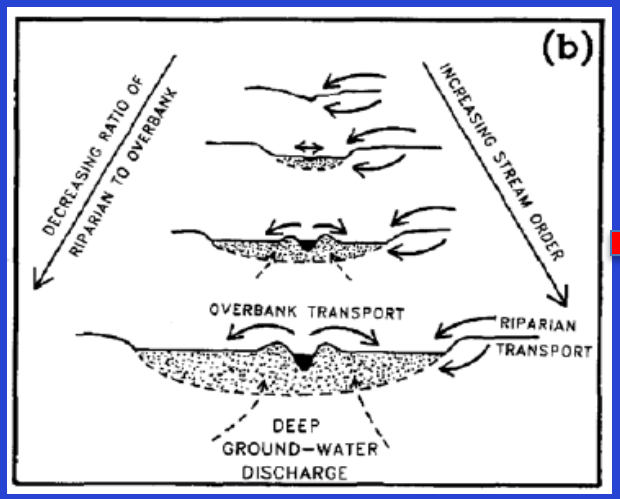
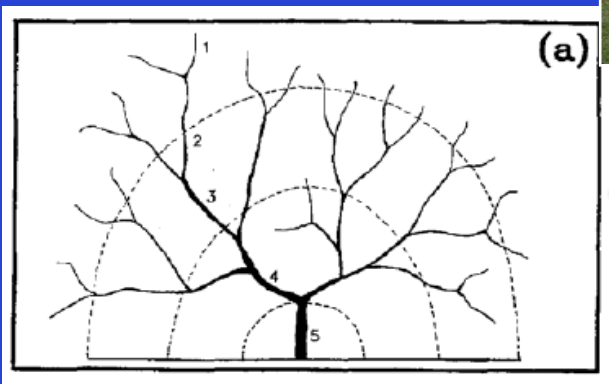




Scale up to drainage network

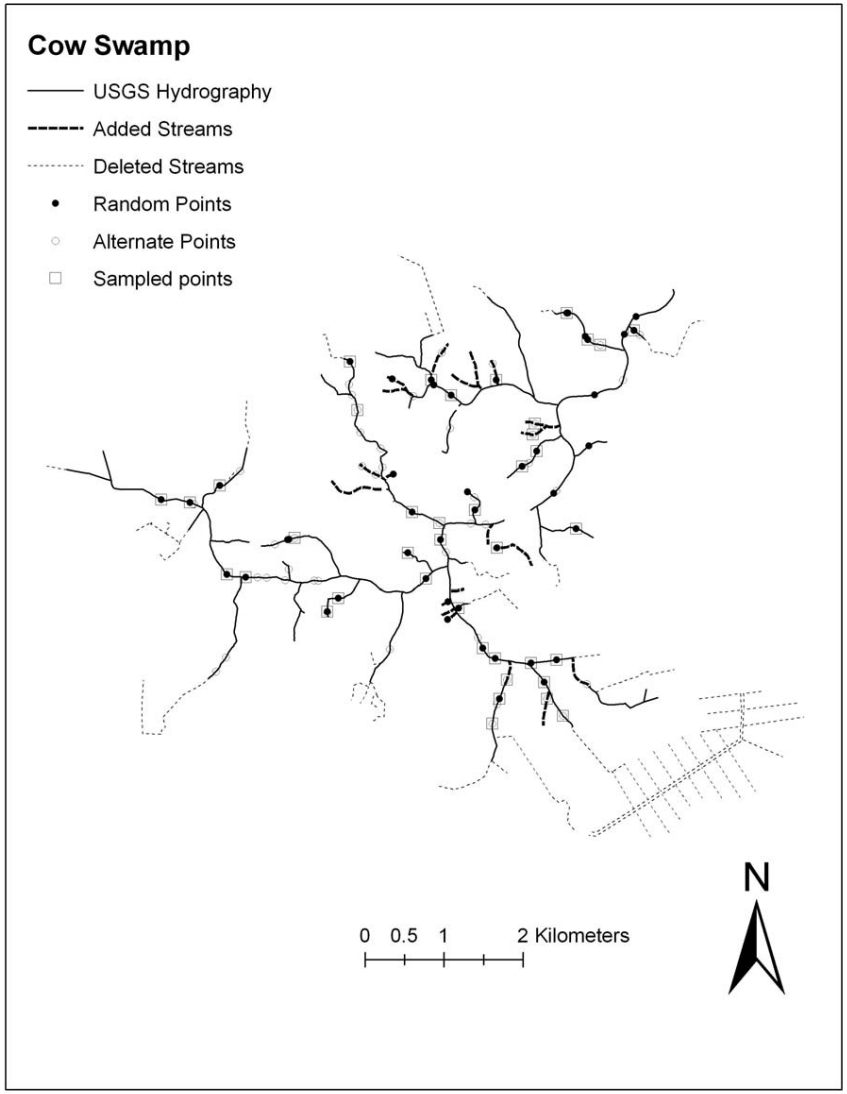




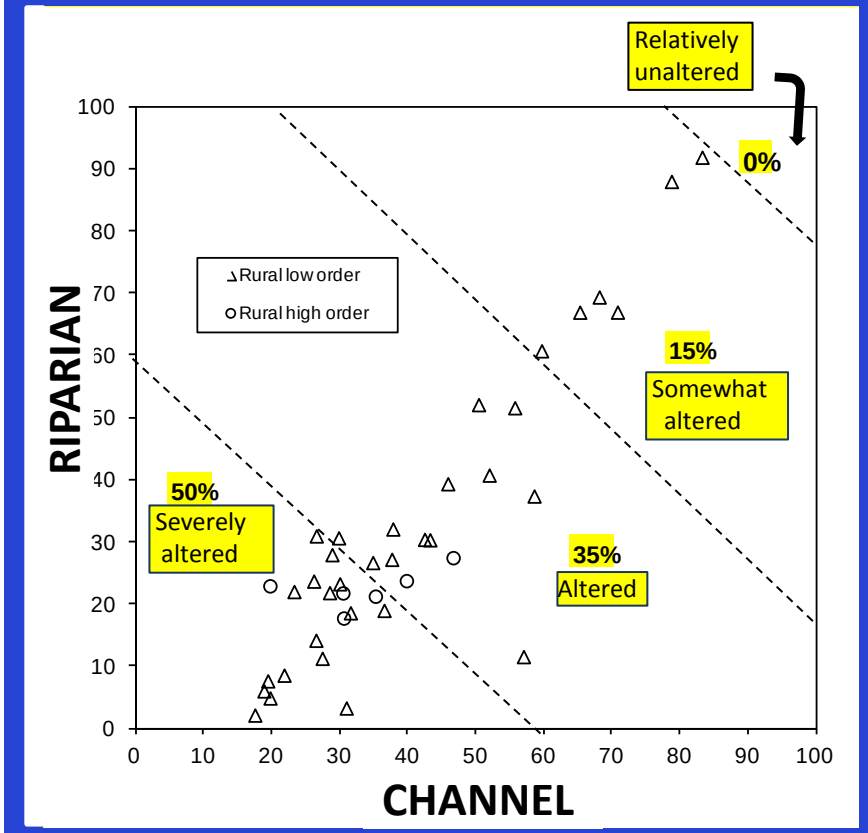
Purpose: Compare basin conditions or track through time

Assessment: Integrate condition of stream reaches in a drainage network (randomized approach)

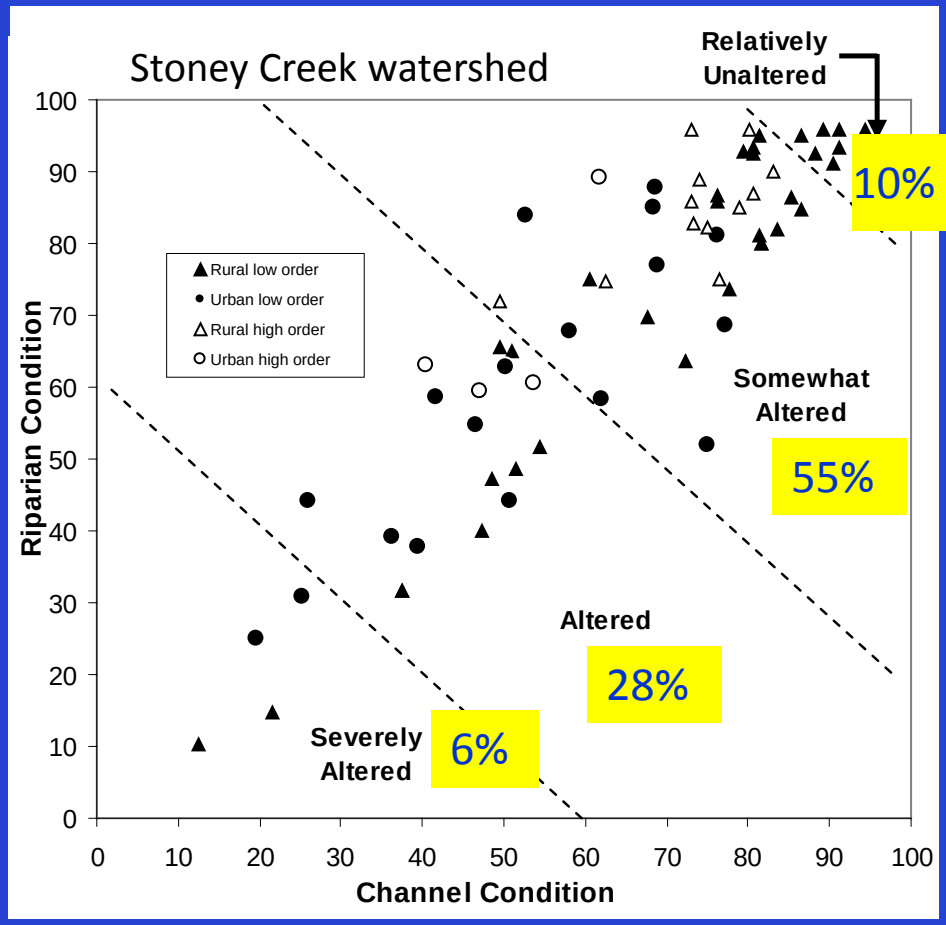
Assess condition of random, 100-m reaches (10%)

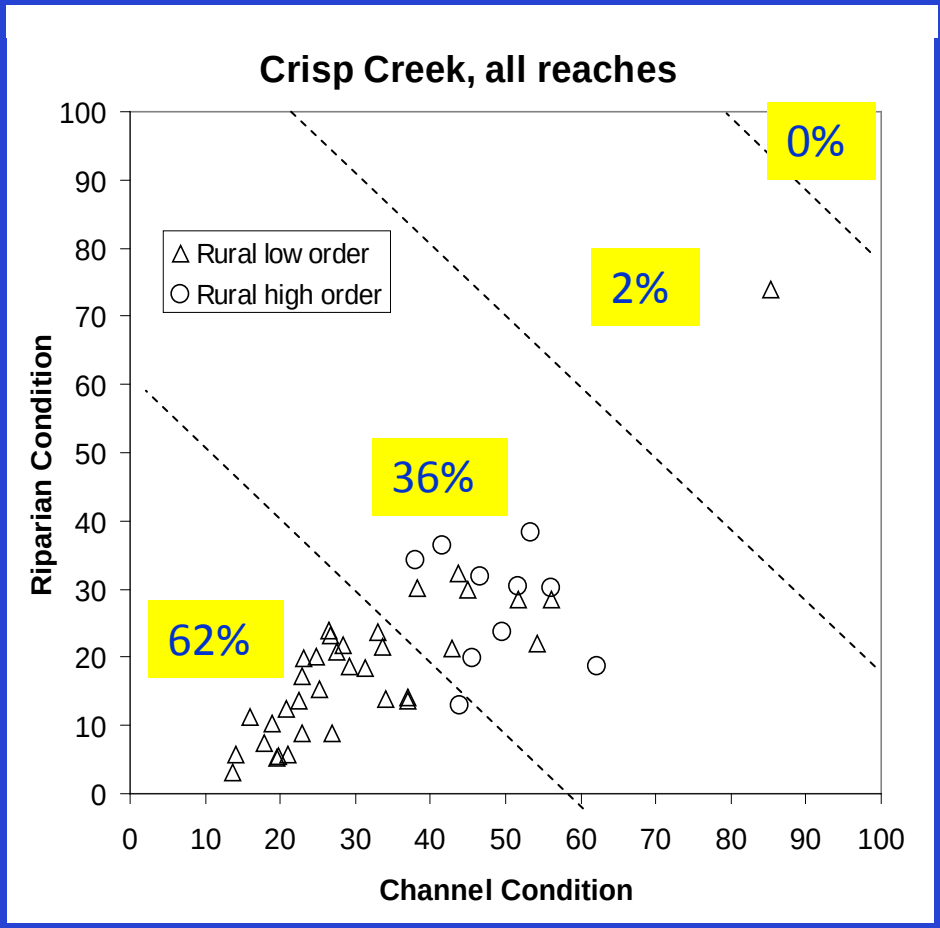


Drainage basin condition



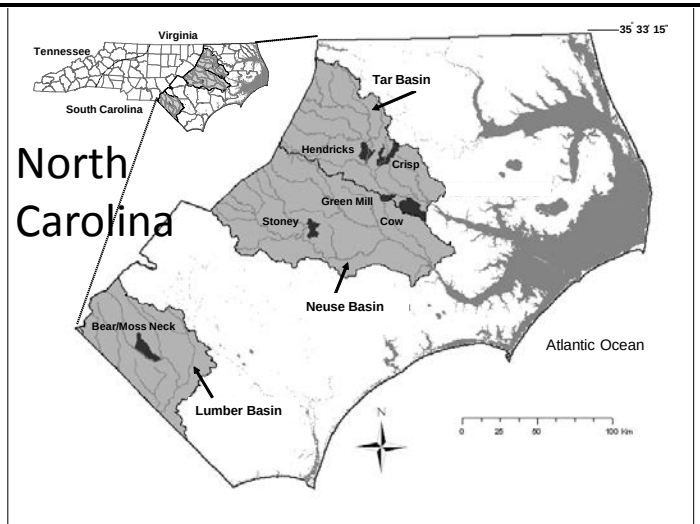
Compare condition between basins or through time





Diagnose problems and prioritize efforts

Watershed (Max score =100)	Riparian zone cover (RZC)	Near-stream cover (NSC)	Instream woody structure (IWS)	Sediment regime (SR)	Channel-riparian zone connection (CRZC)	Pollution affecting stream (PAS)	Factors affecting riparian zone (FARZ)	Habitat quality of riparian zone (HQRZ)	Stream bank stability (SBS)
Cow	38	41	45	31	25	49	29	34	45
Crisp	31	37	44	32	10	45	17	22	44
Green Mill	71	79	66	33	43	54	38	25	45
Hendricks	64	73	61	57	62	65	59	25	31
Stoney	70	72	66	51	67	59	79	60	57
Lumber	43	47	55	30	37	50	44	32	74



Example 3: Using multivariate techniques to monitor tree composition

Variation: space-for-time approach to examine trajectory of tree composition in wet hardwood flats

Condition: ordination position based on composition

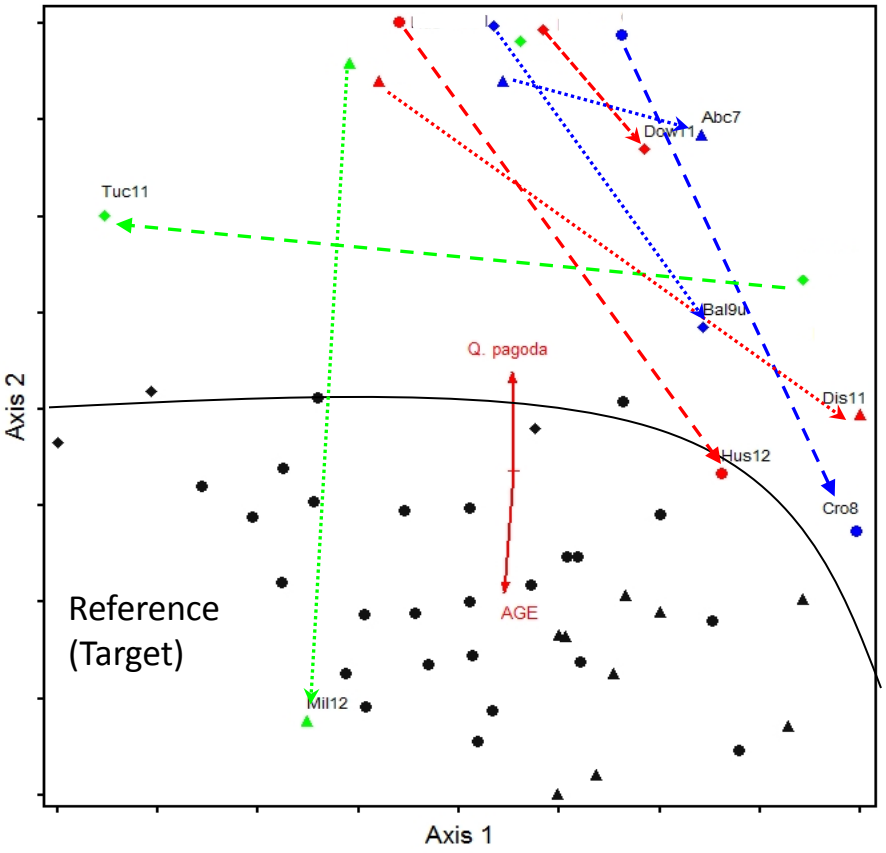
Target: tree composition of mature stands

(Reasonable target?)

Trajectory?

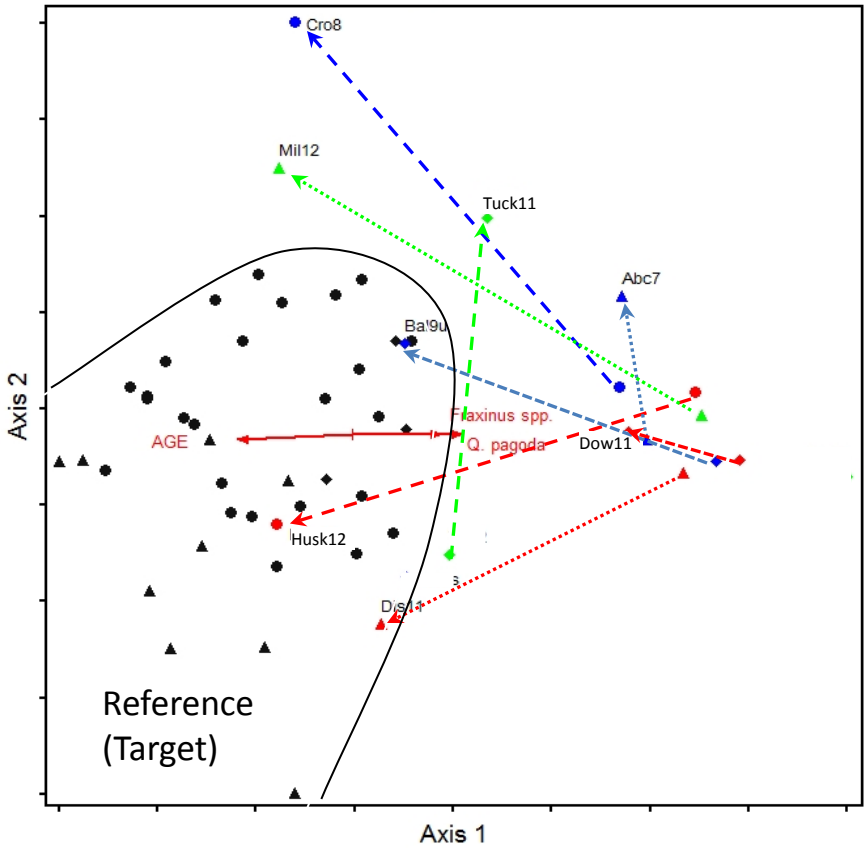
Trajectory Analysis: year1 to year n

Non-metric Multidimensional Scaling



Wet Hardwood Flat
Non-riverine hardwood (CVS)
Hardwood flat (CVS)
Wet hardwood flat (ECU)
Abc (ABC: EEP)
Bal (Ballance: EEP)
Cro (Croatan: EEP)
Dis (Dismal Swamp: EEP)
Dow (Dowd Dairy: EEP)
Hus (Huskanaw: EEP)
Mil (Mildred Woods: EEP)
Tuc (Tucker: EEP)

Polar Ordination



Summary: Common attributes of a successful reference framework

1. Differentiates between natural and human-caused variation
2. Identifies environmental stresses
3. Quantifies condition or functioning using reference data

Restoration only…

4. Identifies potential constraints on recovery
5. Identifies a reasonable target or some intermediate target condition

Acknowledgments

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