Conspicuous Maria Gonds in Transforming the Surface Systems of the Abhujmarh-Highlands – Bastar, India

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"Every isolated passion is, in isolation, insane; sanity may be defined as synthesis of insanities. Every dominant passion generates a dominant fear, the fear of its non-fulfillment. Every dominant fear generates a nightmare, sometimes in form of explicit and conscious fanaticism, sometimes in paralyzing timidity, sometimes in an unconscious or subconscious terror which finds expression only in dreams. The man who wishes to preserve sanity in a dangerous world should summon in his own mind a parliament of fears, in which each in turn is voted absurd by all the others."

―Bertrand Russell

The Kotri River flows in-between Abujhmarh hills of Bastar, India. The highland zone contains what is often called rough country, consisting to a large extent of rugged hills, mountains, and eroded areas frequently broken by valleys and plains. The highest elevations in the Abujhmarh are in the highland zone; the highest point is at 843 m, located in the highlands. The highland zone is cooler than the lowland zone, and receives more rainfall and less sunlight. In many places farming is impossible. Even where it is feasible, the soil is often thin and stony, with a hard rock formation below. Rainwater often cannot escape readily, so many areas tend to be waterlogged.

Abstract: ***Studies of influences of the Maria Gonds of Bastar on the environment may treat the Marias agency as an imposed, exogenous source of change or disturbance or as an intrinsic part of Abhujmarh surface systems. Consideration of the Marias influences as exogenous or endogenous to Abhujmarh surface systems can affect, or even predetermine, the outcome of analyses. This is demonstrated via qualitative stability analyses of generalized***

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mass-and-energy-flux systems. When the Marias impacts are considered as external disturbances such systems are stable, and will regain equilibrium after changes or perturbations. Conversely, when the Marias impacts are included as a system component with goals of either maximizing or minimizing throughout of mass and energy, the system is inherently unstable.

Introduction

Abhujmarh is the least known parts of India which constitutes the southwest part of Bastar division of Chhattisgarh State of India. It is roughly elliptical in shape with longer axis in the northwest, southeast direction. Abhujmarh tract is situated between latitudes 19.0°and 20.0° N and longitudes 80.39' and 81.39° E and spread over about 3,905 sq. km. The Abhujmarh Hills region is conspicuous, because it is wholly comprised of high ridges and deep valleys, the local relief being about 170 to 500 meter, above the plain (Figure:1). This region is about 96 kilometer long, from north to south, and about 56 kilometer broad from east to west. A large part of this area is rugged and dissected by numerous streams. The whole region presents effective physical barrier from all sides (Figure: 2).

Important insights into the nature of the Marias and environment relationships and the impacts of the Marias activity on the Abhujmarh of Bastar have been gained by comparing natural or relatively undisturbed systems with those altered by the Marias activity. Recently the Marias/environment studies have expanded in conceptual scope by treating Abhujmarh surface systems altered by the Marias activity as entities worthy of study in their own right, independently of any comparisons or contrasts with undisturbed analogs (Dongre, 2015). General examples include the developing fields of physical geography and ecology of Abhujmarh. Specific examples include Dongre's (2015) efforts to incorporate the Marias actions and decisions into predictive models of hilly inlet behavior on developed barrier and several studies of the pedology of disturbed land.

Inherent in these different (comparative and no comparative) approaches to the study of the Marias/environment relationships are two contrasting concepts of the role of the Marias agency. In comparative studies of natural and altered systems, mankind is treated as an external factor that perturbs or changes the natural system. Non-comparative studies of altered systems implicitly include the Mariasas a part of the system or at least allow for that possibility. Treating the Mariasas endogenous or exogenous parts of Abhujmarh surface systems raises some fundamental philosophical questions which are beyond the scope of this paper. The question of the Marias role in Abhujmarh surface systems also raises some practical and more immediate questions with regard to system structure and analysis.

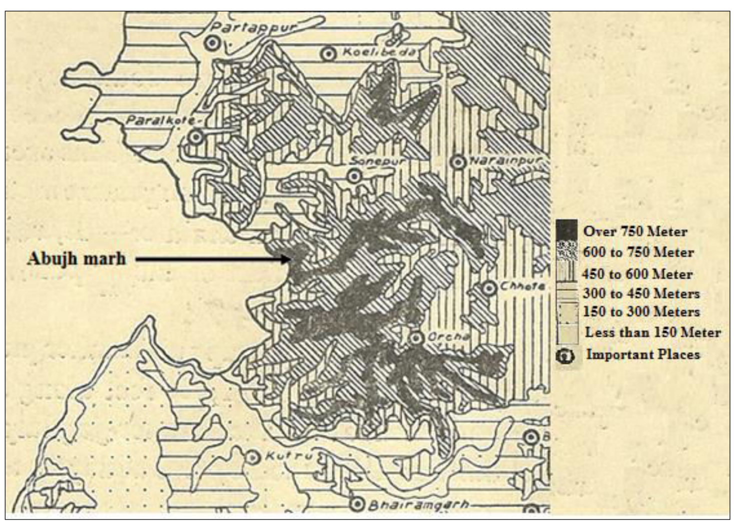

Figure.1. This area of dense forest, mountain, and several rivers is spread over 3, 900² kilometer an area larger than the state Goa. Even today, most of tribal villages in the area remain irascible. The area has population density of less than 10 persons per square mile. Dominated by Abujh Marias, as this area is largely uncharted, in 2009, satellite mapping of region was done by the Indian Space Research Organization.

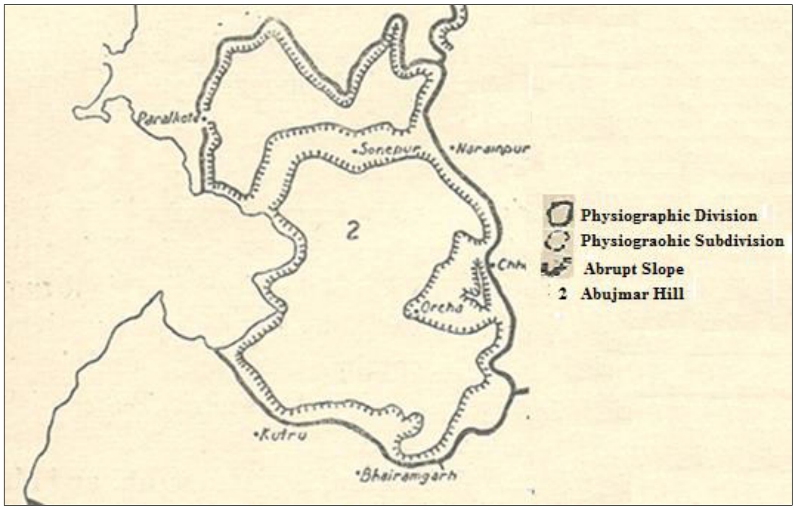

Figure: 2 The Abujhmarh is an isolated region that is surrounded by steep and almost impassible mountain ranges, there lived a small community of a few thousand Marias. Since this region has scarcity of food and other resources and since transportation methods are primitive and the people are generally contented with their resources. There have not been much pressure to face the dangers of crossing the great and forbidding mountains—"the great divide," as they are known. There is disagreement within the community about what lay beyond the mountains. A number of traditions have developed over the years, each of which has its own interpretation of what is on "the other side," as the region beyond the mountains.

The goal of this paper is to explore theoretical aspects of the Marias roles in the functioning of Abhujmarh surface systems. The purpose is to determine the implications of considering the Marias influence as an imposed, external factor or as an internal component of such systems. This will be accomplished by a stability analysis of a generalized mass-and-energy-flux system. Note that the perspective here is that of physical geography and the natural sciences. The results may be of importance for social science and behavioral studies as well, but these are beyond the scope of this paper and the expertise of this writer.

The decision as to which components to include in a system, and the way in which the system is structured can influence or predetermine the outcome of the analysis. This is true whether or not a given study is framed or conducted in formal systems analytic terms. For example, Harvey (1989) reviewed models of the terrestrial global carbon budget and showed that different decisions on what components to include and on how to subdivide the major sinks and transfers of the carbon cycle produced different results, both qualitatively and quantitatively.

The implications of problem formulation influencing or predetermining research results in studies of the Marias/environment relationships are important. In some cases the decision as to whether the Marias agency is to be an endogenous or exogenous factor is imposed by the specific problem or by spatial and temporal scale. Generally the Marias agency may be considered an external factor if the temporal or spatial scale under consideration is an order of magnitude greater than the temporal or spatial scale of the Marias influence on the system, or an internal factor if the scales under study and the scales of the Marias agency are similar in magnitude (the in-between situations are the problem). But in other cases, the decision is a choice of the researcher or a by-product of a particular conceptual framework. In the study of "technogenic" soils (Burykin 1985) or in the broad subfield of physical geography (Douglas 1984), for example, anthropic impacts are treated as an endogenous part of the environmental system. In the comparative approach that contrasts natural or undisturbed areas with man-altered areas, the Marias role is treated as an exogenous factor. There is reason to believe that these choices may influence or even predetermine the qualitative results.

Similar problems may arise with regard to the non Marias perturbations of environmental systems. Generalizations about the treatment of disturbances such as climate change, fires, diastrophism, etc. as endogenous or exogenous factors in environmental systems are unlikely to be the same as generalizations regarding the Marias agency. For this reason, and because of the fundamental relevance of the Marias/environment interactions in geography and other environmental sciences, the focus here will be restricted to the Marias perturbations.

Abhujmarh surface systems

A system is a set of interconnected parts that function together as a complex whole. Abhujmarh surface systems exist at or near the surface of the Abhujmarh and include phenomena such as drainage basins, stream reaches, catenas, hillslopes, soil profiles, ecosystems, and landscapes. Agrawal (1979) provides a detailed discussion of Abhujmarh surface systems and their analysis. The Marias interaction with the biophysical environment can be interpreted and analyzed in terms of Abhujmarh surface systems.

At the most basic level any biophysical system can be characterized as a mass-and-energy-flux system incorporating inputs, outputs and storage (Chorley and Kennedy 1971). The laws of conservation of matter and energy dictate that all matter and energy entering a system must either leave the system (sometimes in the form of dissipated energy or entropy) or are stored within the system. It can be thus developed the simple relationship below, where I is input, $\boldsymbol{O}$ is output, and S storage.

$$\partial I/\partial t - \partial O/\partial t - \partial S/\partial t = 0. \quad (1)$$

Equation (1) must be true for any Abhujmarh surface system. The positive or negative influences of the input, output, and storage variables on each other implied by equation (1) are true with respect to O and S, but input or supply is not dependent upon output and storage. Mass and energy inputs into Abhujmarh surface systems are almost always externally controlled and may be influenced by, but are certainly not controlled by, storage or output of the system. For example, the rate of solar radiation input to an ecosystem is unaffected by the disposition of the energy within the system; or the water and sediment discharge flowing into a river channel reach is not controlled by the discharge from or storage within the reach. For this reason $\partial I/\partial t$ can be treated as given or imposed and write

$$\partial O/\partial \mathrm{t} = \partial I/\partial \mathrm{t} - \partial \mathrm{S}/\partial \mathrm{t}; \quad (2a)$$

$$\partial S/\partial \mathrm{t} = \partial I/\partial \mathrm{t} - \partial O/\partial \mathrm{t}; \quad (2b)$$

This does not imply that input rates are constant. It shows in this case that I is independent of O and S and is externally imposed on the system (that is, a boundary condition). It could be argued that over at least some temporal scales storage within the system influences the supply of matter and energy to the system. Mass and energy fluxes occur along gradients. Storage within the system affects such gradients by influencing mass concentrations and by creating bottlenecks for mass transfer. However, this influence is insignificant over long time periods in affecting input rates compared to the influence of extrinsic factors such as climate. Even at shorter time scales the influence of storage on input can be conceptualized as affecting the allocation of input between entry into storage and direct transfer to output. For this reason input is independent of storage as well as output.

For example, consider precipitation inputs entering a soil surface. Soil moisture does effect the entry of moisture into the soil, as shown in the well-known decline of infiltration rates to a steady-state rate as soils become wetted. However, the variation of infiltration rates with soil wetness influences whether moisture is stored or transported within the soil matrix as soil water, groundwater, or through-flow as opposed to being stored or transported at the soil surface as depression storage or surface runoff. Storage does not affect the actual input of moisture to the soil system.

Equation systems of the form of equations (2) are amenable to the type of analysis described below and in Appendix A. Equations (2) can be translated into a loop or box-and-arrow diagram or an interaction matrix with one additional consideration—the presence of any self-influencing feedback loops. Only the storage component has significant self-regulating feedback. The influence is negative (self-limiting). At high levels of storage the component is self-limiting due to finite capacity. At low

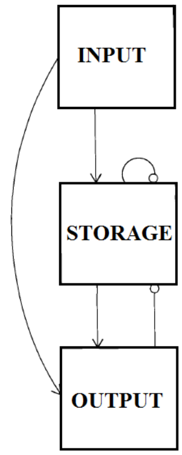

Figure. 3. Signed, Directed Loop Diagram for Generalized Mass/Energy Flux System. Arrows indicate positive relationships; open circles indicate negative relationships (Phillips, 1991).

levels self-limitation occurs due to strong concentration gradients or demand created when storage is low, which will tend to draw more mass/energy into storage. This relationship, along with those defined by equations (2), is shown in Figure 3.

It should be recognized that any link in any of the systems identified here may be negligible in magnitude or nonexistent in a specific situation or at a particular time. However, the stability of the system is a function of whether the links identified are capable of operating in response to changes or perturbations, not necessarily whether they do operate in a specific instance.

Stability of Abhujmarh surface systems

The influence of the Marias activities on Abhujmarh surface systems can be approached by examining the stability of the system shown in Figure 3 in response to disturbances or perturbations associated with the Marias activity. The interaction matrix form of this system is shown in Table 1.

TABLE 1
Interaction Matrix Associated with Figure 3. *I, S*, and *O* are input, storage, and output, respectively.

	I	S	O
I	0	$a12$	$a13$
S	0	$-a22$	$a23$
O	0	$-a32$	0

Asymptotic stability is discussed here. A system is asymptotically stable if, after a perturbation away from equilibrium, the deviation is damped such that the system asymptotically re approaches the pre-disturbance equilibrium state at an exponential rate. Likewise, asymptotically unstable systems diverge from the pre-disturbance equilibrium at an exponential rate after a perturbation. If a new equilibrium is eventually achieved it will not be the same as the pre-disturbance state. Asymptotic stability and instability in this sense can be used to define attractors and repellors in the phase space of nonlinear dynamical systems, despite the fact that the stability is determined by analyzing the linearized form of the system (Thompson and Stewart 1986).

Asymptotic stability, which deals with relatively small perturbations near an equilibrium, is more relevant to the problem at hand than global or complete stability (LaSalle and Lefschetz 1961). Environmental systems are known to be unstable in response to major changes or disturbances such as climate change. It is the response to smaller perturbations that is in doubt. Unfortunately, the distinction between small and larger perturbations is not defined even in a mathematical sense, much less an environmental or geographic sense. In general, however, a finding of asymptotic instability is applicable to disturbances of any magnitude—if a system is unstable in response to small perturbations, it will be unstable in response to larger ones as well (LaSalle and Lefschetz 1961). An asymptotically stable

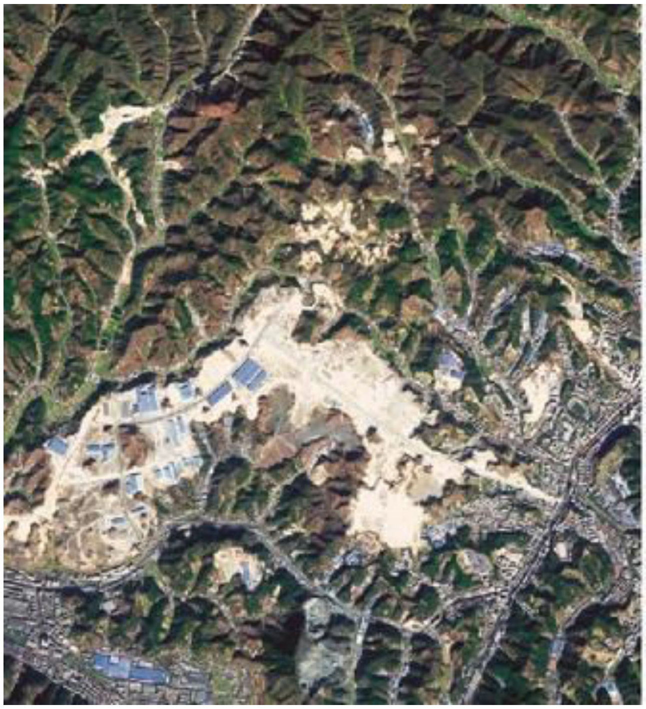

Figure: 4

Figure: 5

Figure-4, Satellite image of Orchha, Bastar (2010). It is a reflection of a better distinction between forested agricultural and built-up land.

Figure: 5 The satellite image (2016), displays the changes in distribution of typical Orchha. Significant changes are detected in surroundings of Orchha subjected to impervious surface and representative of agricultural zone. It epitomizes the rapid extensive single-family houses with ample tree cover. The image also illustrates an important difference between the spectral definition of a developing surface and the isolated surface system.

equilibrium state may be unstable in response to sufficiently large perturbations, but since such a configuration defines an attractor in the system phase space, the system history or trajectory will ultimately return to such a state (Thompson and Stewart 1986).

In the context of this study small perturbations are referred to and assumed to be no catastrophic. Catastrophic disturbances are intuitively defined here as perturbations such that at least some of the feedback mechanisms within the system are obliterated or substantially altered. These days Mariasare creating new land for development. The Satellite image of 2010 (Figure: 4) raises concerns about this enormous development in and around Orchha. The Satellite image of 2016 (Figure: 5) shows, over 78 square kilometers of land are being created by removing the tops of mountain and filling the surroundings. This is the outskirts of Orchha for example as shown in an image collected. The enormous change is clearly evident. The scale of this change is immense in removing the hills and the area is developing for agriculture and residential sides also. Immense development or the lining of a channelized stream with concrete would be examples. For specific systems with numerical data terms such as "small" perturbations and time periods such as "ultimately" as used above can be more precisely defined.

The system shown in Figure 3—or any system so defined—can be translated into an interaction matrix A (for example, Table 1) whose elements a_{ij} represent the positive, negative, or zero influence of the row component on the column component. Despite the fact that the elements a_{ij} cannot be qualified for the general case, the stability of the system in response to a perturbation x at time t from an equilibrium state C can be determined. The technique for doing so is often called qualitative asymptotic stability analysis, and is applicable to small disturbances near equilibrium. It is discussed in detail by

Puccia and Levins (1985) and more succinctly by Levins (1974) and Slingerland (1981). A summary of the mathematics involved in the solution used here is given in Appendix A.
The technique has been used successfully in several applications in geomorphology, hydrology, pedology, and ecology (Slingerland 1981; Puccia and Levins 1985; Scheidegger 1983, 1988; Phillips 1985, 1987, 1989, 1990; Giavelli and Bodini 1990).

Every solution with respect to system response to a perturbation is of the form (Appendix A):

$$x(t) = \text{vC} \exp(\lambda t) \tag{3}$$

where **v** are the eigenvectors and λ the eigenvalues of A.

The response of the system depends on the real parts of the eigenvalues. If any is positive the deviation increases exponentially through time and the system is unstable. If all are negative the deviation is damped through time and the system asymptotically re-approaches its pre-disturbance state. If one eigenvalue has zero real part with all others negative, the system may be metastable or unstable (Braun 1983). The Routh-Hurwitz criteria (Braun 1983; Puccia and Levins 1985) state that the real parts of all eigenvalues will be negative if and only if

$$a_i > 0 \text{ for all } i; \text{ and} \tag{4}$$

$$a_1 a_2 - a_3 > 0 \text{ for } n = 3 \text{ or} \tag{5a}$$

$$a_1 a_2 a_3 - a_3^2 - a^4 a_2^1 > 0 \text{ for } n = 4. \tag{5b}$$

The a_i are coefficients of the characteristic polynomial of A. The n = 4 case will be relevant in the next section.

For the system shown in Figure 3 the conditions above and the simple sufficient criteria for stability given by May (1973, p. 71) and in Appendix- A are met. The system is thus stable in response to non-catastrophic the Marias disruptions or perturbations. This asymptotic stability suggests that if the system is allowed to recover after non catastrophic the Marias disturbance the mass-flux system can return to a state similar to its pre-disturbance condition. Thus the system is stable if the Marias agency is treated as an exogenous factor or source of perturbations.

The Marias agency as an intrinsic factor

In the preceding analysis the Marias activity is treated as an exogenous, imposed disturbance of the generalized mass flux system (flux and storage may involve matter and/or energy, but the term mass flux system is used here for brevity). In this section the Marias will be treated as an intrinsic part of the mass-flux system. Because the Marias have the ability to change Abhujmarh surface systems to such a great degree, the Marias will be incorporated as a system component of the mass flux system along with input, storage, and output.

Two simple situations with regard to the Marias goals for mass flux systems are considered. First, the Marias may want to minimize storage and input and maximize output. This would be the case, for example, with regard to a river channel used for irrigation and the flux of sediment and other solid debris. The goal would be to minimize in-channel debris storage and input of debris to facilitate irrigation. Maximum output or removal of debris would be desired. Second, the Marias may want to maximize input and storage and minimize output. This would be the goal with regard to runoff in a water-harvesting scheme, or with regard to solar energy flux in an agro ecosystem. These cases will be analyzed separately. the Marias controlled mass fluxes can be symbolically represented as $\partial M/\partial t$, which represents a flux to or from the Marias. In a hydrologic system, for example, artificial drainage or irrigation may be considered mass fluxes to or from the Marias-controlled sources or sinks.

Minimization of Storage and Input

In this case the system is constructed by starting with Figure 3 and adding the Marias influences and the linkages between the Marias (denoted by "man" in figures for brevity; no gender connotation intended) and other components. The Marias agency would have a negative or negligible impact on input (depending on the ability to control supply of matter or energy), as the goal is to minimize input and storage. The Marias would have a negative influence on storage, and a positive influence on output. The flux is from storage to the Marias, and thence from the Marias to output, based on the assumption that the Marias will respond to storage in their manipulation of the system (thus no link from input directly to the Marias). This assumption is viable for the majority of cases envisioned—for example, the Marias respond to soggy ground and swollen rivers or dry soil and low flows, not to precipitation inputs. Therefore storage will have a positive influence on the anthropic fluxes in this case, as increased storage will result in increased the Marias efforts to remove it or to limit supply. Decreased storage would result in lower levels of the Marias manipulation. This system is shown diagrammatically in Figure 6, and in the interaction matrix of Table2.

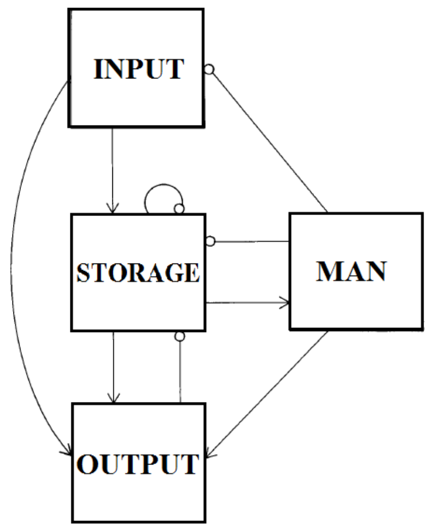

Figure. 6. Signed, Directed Loop Diagram for Generalized Mass/Energy Flux System, with "Man" Indicating the Marias-Controlled Mass Fluxes. The assumption in this case is that the Marias seeks to minimize storage and input and to maximize output.

The characteristic equation of the matrix in Table 2 is

$$\lambda^4 - (-a_{22})\lambda^3 + [-(-a_{32}a_{23})]\lambda^2 - [a_{2A}\{-a_{32}\}a_{43}]\lambda$$

$$+a_{13}(-a_{22} + a_{2A} + \{-a_{32}\} + \{-a_{41}\} + \{-a_{42}\}) = 0.$$

Coefficients one, two, and three are positive.

The fourth coefficient of the characteristic equation will not be positive unless

$$a_{24} > a_{22} + a_{32} + a_{41} + a_{42}. \quad (7)$$

This would be true only if the rate of mass removal by the Marias activity in response to storage change was greater than the combined rates of all four links on the right of the inequality. Matrix elements a_{32} and a_{42} represent all removal from storage; together they must equal or exceed the maximum rate of the Marias-caused storage change represented by a_{24} Therefore the inequality cannot be satisfied, and the fourth coefficient cannot be positive. The system is unstable.

The system instability means that in response to a change or perturbation the system will not return to its pre-disturbance state. Rather, the system will continue to deviate further from the preexisting equilibrium. The instability exists because the Marias responses to changes in components of the mass/energy flux act to override the deviation-damping feedback responses that would dominate the system if there were no further the Marias involvement.

TABLE 2
Interaction Matrix Associated with Figure *6.* Assumption is that The Marias (*M*) seek to minimize input ($\boldsymbol{I}$) and storage ($\boldsymbol{S}$) and maximize output($\mathbf{0}$) .

	I	S	O	M
I	0	$a12$	$a13$	0
S	0	$-a22$	$a23$	$a24$
O	0	$-a32$	0	0
M	$-a41$	$-a42$	$a43$	0

Maximization of Storage and Input

In this case assumptions are similar to those above but the goal is to maximize storage and input and to minimize output. The system is shown in Figure 7 and the interaction matrix in Table 3. The latter is similar to the matrix in Table 2 except that the signs of elements a_{24} a_{41} a_{42} a_{43} have been reversed. Likewise the characteristic equation is the same as equation (7) except for the reversal of the appropriate signs. In this case, though coefficients one and two are positive, coefficient three must always be negative. Therefore the system is unstable.

Whether the Marias goals are maximization or minimization of a mass flux system, the general system is unstable when the Marias influence is considered intrinsic to the system. The implications will be discussed further after the case study below.

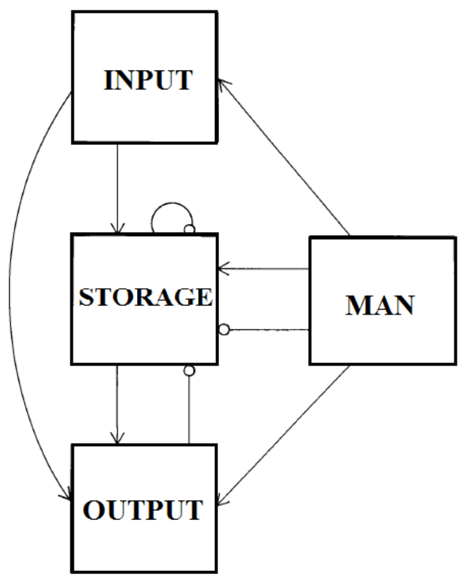

Figure. 7. Signed, Directed Loop Diagram for Generalized Mass/Energy Flux System with the Marias-controlled Mass Fluxes ("Man" above) Included. Assumption in this case is that the Marias seek to maximize storage and input and to minimize output.

TABLE 3
Interaction Matrix Associated with Figure *7.* Assumption is that the Marias($\boldsymbol{M}$)se ek to maximize input ($\boldsymbol{I}$) and storage ($\boldsymbol{S}$) and to minimize output ($\boldsymbol{O}$).

	I	S	O	M
I	0	$a12$	$a13$	0
S	0	$-a22$	$a23$	$-a24$
O	0	$-a32$	0	0
M	$a41$	$a42$	$-a43$	0

Example. Radial drainage in Abhujmarh

The general principles developed above can be demonstrated by an example involving the Marias modifications to the hydrologic system in highlands of the Bastar. This example is chosen because the hydrologic modifications in this area have been examined by the author in several other contexts. Shrub bog wetlands called pocosins have been extensively drained by artificial ditch-and-canal systems to facilitate agriculture and forestry. The goal is to lower water tables, reduce surface ponding, and reduce the amount of time the soil is saturated to facilitate crop growth and increase traffic ability.

The moisture mass budget system independent of the Marias activity involves inputs provided by precipitation, storage of moisture as soil moisture, groundwater, or surface depression storage, and output in the form of runoff and evapotranspiration. Input has a positive influence on both storage and output. Output has a negative influence on storage, as runoff and evapotranspiration will be derived from stored moisture between precipitation events. Storage has a self-limiting loop. During wet conditions storage limits may be reached and exceeded as soil moisture storage capacity is filled and water tables rise to the surface. Saturated conditions also facilitate more rapid groundwater flow out of the system. At low moisture levels soil tension retains moisture to prevent complete dessication, and provides for more rapid infiltration at the onset of the next precipitation event. The diagram describing this system would be identical to Figure 3.

Like the generalized system described earlier, the soil hydrologic system independent of the Marias influence is stable in response to sub catastrophic perturbations. The system meets the simple sufficient conditions for stability (Appendix A; May 1973, p.71). Therefore if man's influence is considered to be an external perturbation the system is regarded as stable in response to such perturbations.

Now consider the influence of the Marias who desire to maintain drainage conditions suitable for commercial agriculture and forestry. Storage has a positive influence on man, as the Marias manipulate the system (via water control structures in drainage canals, clearing of ditches and canals, ditch construction, etc.) to increase withdrawals. These withdrawals leave the system as runoff, so $\partial M/\partial t$ has a positive link to outputs and a negative link to storage. In this case the Marias activity cannot significantly influence input rates, so there is no link to inputs. The diagram describing the system is shown in Figure 8 and the associated interaction matrix in Table 4.

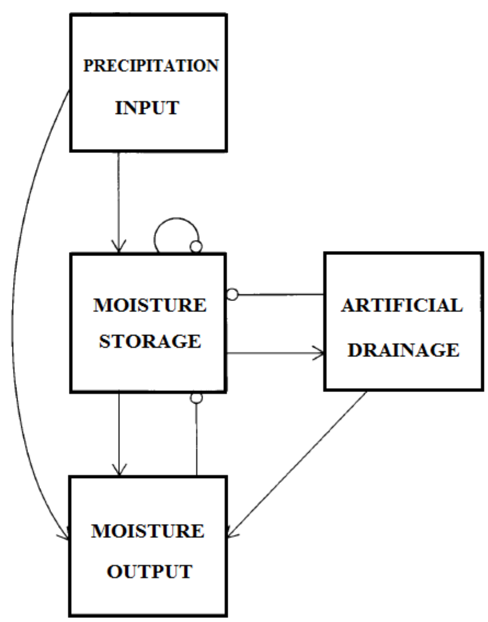

Figure. 8. Signed, Directed Loop Diagram for Soil Hydrologic System Described in Case Study in Text.

The characteristic polynomial is

$$\lambda^4 - (-a_{22})\lambda^3 + [-(-a_{32}a_{23})]\lambda^2 - [a_{2A}\{-a_{32}\}a_{43}]\lambda$$
$$+a_{13}(-a_{22} + a_{2A} + \{-a_{32}\} + \{-a_{41}\} + \{-a_{42}\}) = 0. \quad (8)$$

The first three coefficients are positive. The fourth would be positive if

$$a_{24} > a_{22} + a_{32} + a_{41} + a_{42}. \quad (9)$$

TABLE 4
Interaction Matrix for the Abhujmarh Drainage Example Discussed in the Text, Derived from Figure 4. PI = precipitation input; MS = moisture storage; MO = moisture output; and AD = artificial drainage.

	PI	MS	MO	AD
PI	0	$a12$	$a13$	0
MS	0	$-a22$	$a23$	$a24$
MO	0	$-a32$	0	0
AD	0	$-a42$	$a43$	0

In this case $a_{24} \leq a_{42}$ because the influence of a storage change on the rate of moisture removal by the Marias cannot be greater than the ability of the artificial drainage system to reduce storage. The relation cannot be true, and the Routh-Hurwitz criteria hold that the system cannot be stable.

Therefore if the Marias hydrologic modifications are treated as an external perturbation to the hydrologic system, the system is stable in response to drainage modifications and could be expected to recover to a state near its pre-artificial drainage state. If man is considered as a part of the system which consistently responds to other components of the system as reflected in moisture storage (soil moisture, groundwater, and depression storage), the hydrologic system is unstable and will not recover following a disturbance or perturbation of any kind.

This result is verified by studies of the Marias hydrologic modifications in eastern Abhujmarh Bastar. There is gradual recovery of equilibrium in a small artificially drained watershed of the region, where equilibrium was defined on the basis of correlations between monthly values of moisture surplus and stream discharge. High correlations (Pearson's $r \geq 0.8$) existed before construction of artificial channels, and three to five years after construction or rehabilitation of artificial channels. Low correlations ($r \leq 0.6$) existed immediately after construction or renovations of channels. This pattern reflects the feedback responses to disturbance (loss of water-carrying capacity in ditches and canals) and the response of land managers to the recovery of hydrologic equilibrium (that is, clearing out clogged channels). On theoretical grounds that stability of artificially drained of the eastern Abhujmarh Bastar depended on the extent to which ditches and canals were allowed to deteriorate without further the Marias intervention. The exponential decline in water-conveying capacity of un-maintained canals was documented by Phillips (1988).

Belk (1990) found no significant differences in hydrologic status between undisturbed pocosin wetlands, formerly drained pocosins recently restored by blockage of artificial channels, and formerly drained pocosins where ditches and canals have not been maintained for several decades. Using the method of Novikov and Goncharova (1981), Belk (1990) also calculated the water availability (units of depth moisture in the soil profile per unit surface area) of undisturbed and artificially drained wetlands, as well as artificially drained wetlands which had been undisturbed for two decades or more since canals were constructed (post-altered sites). All sites were in close proximity and of similar total depth. The calculations were based on field data on water table elevations, soil moisture storage, soil subsidence, and evapotran spiration. The stability model would suggest that the water availability of the post-altered sites would be similar to that of the undisturbed site (presuming the latter represents equilibrium). The altered sites should have significantly different water availability. The results confirmed the predictions of the stability model, as water availability was 0.551 m/m^2 for the undisturbed site; 0.386 at the altered sites, and 0.549 at the post-altered sites (Belk 1990). Clearly, the system is stable in response to singular or infrequent the Marias disruptions (the Marias agency exogenous) and would likewise be unstable if the Marias actions were frequent and artificial channels periodically renovated.

In this example problem, if the temporal and spatial scales of investigation were clearly limited to times and places undergoing active the Marias manipulation of the hydrologic system, it is clear that the Marias agency should be considered an endogenous component. Likewise, if the scales of the problem are defined such that the time span under investigation is large compared to the time of active hydrologic manipulation, it would be appropriate to view the Marias agency as a factor external to the hydrologic system.

Suppose, however, that the research goal is a broad determination of the extent to which artificially drained pocosins can restore the pre-drainage hydrologic regime. Unless the issues raised above are specifically addressed, the study design itself could actually predetermine a conclusion that artificially drained pocosins can or cannot recover from hydrologic modifications, depending on the temporal scale chosen for investigation and/or the timing and frequency of the Marias activity at the study locations.

Discussion and conclusions

The model of mass-flux systems presented here and the simple cases of the Marias maximizing or minimizing storage and input or output cannot represent, even in a very general way, all the Marias-influenced Abhujmarh surface systems. In other words, it is conceded that exceptions can be identified. However, the generalized system is believed to be representative of Abhujmarh surface systems, however debatable specific points might be when applied to particular cases. Certainly there are enough the Marias-altered systems that can be generally represented by the model to lend validity to the major point of the modeling exercise—to show that consideration of the Marias agency as an endogenous or exogenous factor can influence or predetermine the outcome of analyses of Abhujmarh surface system response to the Marias activity.

The immediate implications of these results are relevant to the study of the Marias/ environment relationships and the Marias influence on natural systems. In any such study, the behavior of the system may depend on whether the Marias agency is considered to be an external factor which disturbs or perturbs the natural system, or an internal part of the system. It has been shown for a generalized mass/energy flux system that the relationship between inputs, output, and storage is stable in response to sub-catastrophic disturbances. After such disturbances the system will return to a state near its previously existing state. If the Marias influences are viewed in this context Abhujmarh surface systems are stable and nature can accommodate all but the most severe the Marias impacts.

Conversely, the Marias agency can be considered part of such mass/energy flux systems, usually with definite goals regarding maximization or minimization of storage and inputs in a particular system. In this case the analysis shows that the system is unstable and will not regain equilibrium after a perturbation.

Obviously to some extent the difference depends simply on the duration and persistence of the Marias influences on the environment. In other cases, however, the consideration of man as an intrinsic or extrinsic factor in Abhujmarh surface systems is a choice of the researcher or an outcome of the spatial or temporal scale of analysis. In the latter cases one should always be aware that the conceptualization of the Marias role itself will influence—or even determine—the outcome of analysis.

If the conceptualization of the Marias agency is not a clear, logical outcome of the research problem or study design, these results suggest that it is most appropriate to treat the Marias factor as an intrinsic part of Abhujmarh surface systems. Treating the Marias as exogenous may result in an overly optimistic assessment of the ability of Abhujmarh surface systems to adapt to or recover from the Marias alteration. Including the Marias agency as an endogenous factor—especially when the agency is persistent or recurrent—is more likely to detect persistent or recurring disequilibria.

There are broader implications for environmental management which need further exploration. Results here imply that management strategies based on short-term resource utilization or exploitation followed by fallow periods which allow system recovery are preferable to strategies based on persistent or recurrent manipulation, however benign such the Marias manipulation may be (and assuming the stable semi natural state is desirable). This would suggest, for example, that the intensive use followed by extensive rest range management techniques propounded by Savory (1988) are superior to grazing strategies based on year-in-year-out the Marias manipulation over a broad area. Savory's ideas are quite controversial in the range management field, and future work will focus on evaluating environmental management strategies in the context of endogenous versus exogenous roles of the Marias agency and qualitative system stability.

This analysis raises a fundamental methodological question as to what extent the endogenpus or exogenous role of the Marias agency is real (that is, a function of the problem at hand) or perceptual (a function of the views, conceptual framework, or methodology of the researcher). Unfortunately at this point one can do little more than raise the question and point to the need for investigators to clearly identify and justify their treatment of the Marias agency.

Appendix a. Qualitative stability analysis

Let A be an $(n \times n)$ interaction matrix whose elements a_{ij} represent the positive, negative, or zero influence of the ith component on thej'th component. The sufficient conditions for stability of A are

(May 1973, p. 71):
*For all i: $a_{ii} \leq 0$
*For at least one i: $a_{ii} \neq 0$;
*For all $i \neq j$; $a_{ij}a_{ji} \leq 0$;
*For any sequence of three or more indices $i, j, k \dots p, q$; $i \neq j \neq k \neq \cdots \neq p \neq q$: $a_{ij}a_{jk} \dots a_{pq}a_{qi} = 0$;
*det A $\neq$ 0.

If all five conditions are met the system is stable. If any condition is not met the system may be stable or unstable depending on the relative strengths of the links between system components. In these cases stability may be determined from the characteristic polynomial of A. The development below follows Levins (1974), Slingerland (1981), and Phillips (1987).

The interaction matrix represents a system of n variables or components X (a vector) whose levels vary over time (t) as functions (F) of each other. Thus,

$$dX/dt = \mathrm{F(X)} \qquad \text{(A1)}$$

System components adjust individually based on conditions given by the other components. A solution is possible in the qualitative sense even if the form of F is not known, as long as it is known whether any component is increased, decreased, or unaffected by a given change in another component.

Let C be an equilibrium point for the system. A deviation or perturbation x from equilibrium is given by

$$\mathrm{x = X - C.} \qquad \text{(A2)}$$

Then the change over time of the system is

$$\boldsymbol{dX/dt = F(\mathbf{x} + \mathbf{C})} \qquad \text{(A3)}$$

The right side of the preceding equation can be rewritten via Taylor expansion (Braun 1983) to yield

$$\mathbf{F}(\mathrm{x} + \mathbf{C}) = \mathbf{F}(\mathbf{C}) + \mathrm{Ax} + \mathrm{g(x)}$$

where g (X) is a vector of polynomials of order ≥ 2, each small compared to x, and vanishing at x = 0. The elements of A are of the form

$$\boldsymbol{a_{ij}} = \boldsymbol{\partial F_i}(C)/\partial X_i \qquad \text{(A5)}$$

With respect to small deviations x, g(x) is very small compared to Ax. It is sufficient in this case to evaluate the linearized system

$$\boldsymbol{dX/dt} = \text{Ax}. \qquad \text{(A6)}$$

Note that this limits the analysis to small deviations and state space near an equilibrium. It does not apply to large deviations or situations where the predisturbance state is far from equilibrium. Every solution is of the form

$$x(t) = \text{vC} \exp(\lambda t) \qquad \text{(A7)}$$

where v are eigenvectors of A associated with eigenvalues $\boldsymbol{\lambda}$. This is identical to equation (4) in the text.

The system is stable if and only if all eigenvalues of A are negative. The Routh-Hurwitz criteria establish necessary and sufficient conditions for the case that the real part of the roots of the characteristic polynomial is negative. These are

$$a_i > 0 \text{ for all } i, \text{and} \qquad \text{(A8)}$$

$$a_1 a_2 - a_3 > 0 \text{ for } n = 3 \text{ or} \qquad \text{(A9a)}$$

$$a_1 a_2 \boldsymbol{a_3} - \boldsymbol{a_3^2} - \boldsymbol{a^4} a_2^1 > 0 \text{ for } n = 4 \qquad \text{(A9b)}$$

These correspond to equations (5) and (6) in the text.

From mountains of Orchha-Minerals remains are the geochemical and mineralogical memory of parent rocks across ancient weathering covers- the small bodies comprised in a larger domain included- keeping individuality during weathering.

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