The Vulnerability-Resilience Indicators Model
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The Vulnerability-Resilience Indicators Model (VRIM) (Moss et al. 2001, Brenkert and Malone 2005) identifies 17 factors (listed in the table below) that together assess the vulnerability of a society. Managed and unmanaged land, economic activities that are natural-resource-intensive, and socioeconomic characteristics are represented.

SECTORAL INDICATORS	PROXY VARIABLES	PROXY FOR
Food security	Cereals production/ crop land area	Degree of modernization in the agriculture sector; access of farmers to inputs to buffer against climate variability and change
	Protein consumption/ capita	Access of a population to agricultural markets and other mechanisms (e.g., consumption shift) for compensating for shortfalls in production
Water resource sensitivity	Renewable supply and inflow of water	Supply of water from internal renewable resources and inflow from rivers divided by withdrawals to meet current or projected needs
Settlement/ infrastructure sensitivity	Population at flood risk from sea level rise	Potential extent of disruptions from sea level rise
	Population without access to clean water	Access of population to basic services to buffer against climate variability and change
	Population without access to sanitation	
Human health sensitivity	Completed fertility	Composite of conditions that affect human health including nutrition, exposure to disease risks, and access to health services
	Life expectancy	
Ecosystem sensitivity	% Land managed	Degree of human intrusion into the natural landscape and land fragmentation
	Fertilizer use/ cropland area	Nitrogen/phosphorus loading of ecosystems and stresses from pollution
Human and civic resources	Dependency ratio	Social and economic resources available for adaptation after meeting other present needs
	Literacy	Human capital and adaptability of labor force
Economic capacity	GDP(market)/ capita	Distribution of access to markets, technology, and other resources useful for adaptation
	An income equity measure	Realization of the potential contribution of all people
Environmental capacity	% Land unmanaged	Landscape fragmentation and ease of ecosystem migration
	SO_2/area	Air quality and other stresses on ecosystems
	Population density	Population pressure and stresses on ecosystems

The VRIM has been used to compare 160 countries (Malone and Brenkert 2009), evaluate adaptive capacity at temperature increases of 1.5°C and 4.5°C (Yohe et al. 2006a,b), analyze India and Indian states under current conditions (Brenkert and Malone 2005) and future scenarios (Malone and Brenkert 2008), and examine resilience in Mexico and Mexican states (Ibarraran et al. 2010).

The VRIM is a hierarchical model with four levels. The vulnerability index (level 1) is derived from two indicators (level 2): sensitivity (how systems could be negatively affected by climate change) and adaptive capacity (the capability of a society to maintain, minimize loss of, or maximize gains in welfare). Sensitivity and adaptive capacity, in turn, are composed of sectors (level 3, the left-hand column of the table). Each of these sectors is made up of 1-3 proxies (level 4, the middle column of the table). Each of the hierarchical level values is comprised of the geometric means of participating values. Proxy values are

indexed by determining their location within the range of proxy values over all countries or states. The final calculation is the geometric mean of the sector values.

The indexing methodology is given in the following table:

	VRIM Range Method for indexing
Steps in the hierarchy	- geometric mean of proxies > sector indices - geometric means of indices > sensitivity or coping-adaptive capacity - geometric mean of sensitivity and coping-adaptive capacity indices > VRIM index
Sensitivity index	kept as positive value
Indexing	based on the range of values
Log transforms	- income (per capita GDP) - sulfur deposition - water sensitivity
Determination of the scaled proxy value; alternatives depend on its value	Shift + $\frac{100 * (P - Pmin)}{(Pmax - Pmin)}$
	Shift + $\frac{100 * (Pmax - P)}{(Pmax - Pmin)}$

P is the country or state's proxy or indicator value

Projections are made using variants of the scenarios from Nakicenovic and Swart (2000). The fluctuations of the vulnerability-resilience index and the varying importance of the various indicators over time show that the model is accounting for initial values, interactions among the proxies and dynamics over time, and the model structure. The two SRES-based scenarios exhibit differences not only in overall pathways, but also in the indicators that dominate the explanation of the uncertainty as the century unfolds. These differences provide decision makers with preliminary insight about how various development strategies might contribute to resilience.

Uncertainty analysis of the model demonstrates that the model is actually providing analysis and not simply yielding responses based on initial inputs. Each of the 17 proxies has a chance to contribute to the overall vulnerability-resilience index, and those contributions can change over time as different scenarios unfold over the course century-long projections.

References

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