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A "Resource-Literate" Explanation of Differences between Two Droughts in Maharashtra: (*1*) in the mid-1970s and (*2*) in 2012

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Drought in Maharashtra in the 1970s began in the wake of a rather weak monsoon in 1971 (with hardly more than half of normal rainfall) and got worse with an even weaker one in the next season, and again weak in 1973; crop failures in Maharashtra were grave in 1972 and '73.[1] The drought in 2012, causing Maharashtra's overall crop production (measured in terms of weight) and productivity (weight per crop-area) to be some 20% lower than normal,[2] was due to a *slightly* weak monsoon (with some 90% of normal rainfall for the state as a whole)[2] and to some other, man-made causes. How these latter causes aggravated the agricultural effect of a slightly weak monsoon can be explained by using some basic concepts and terms of soil science.

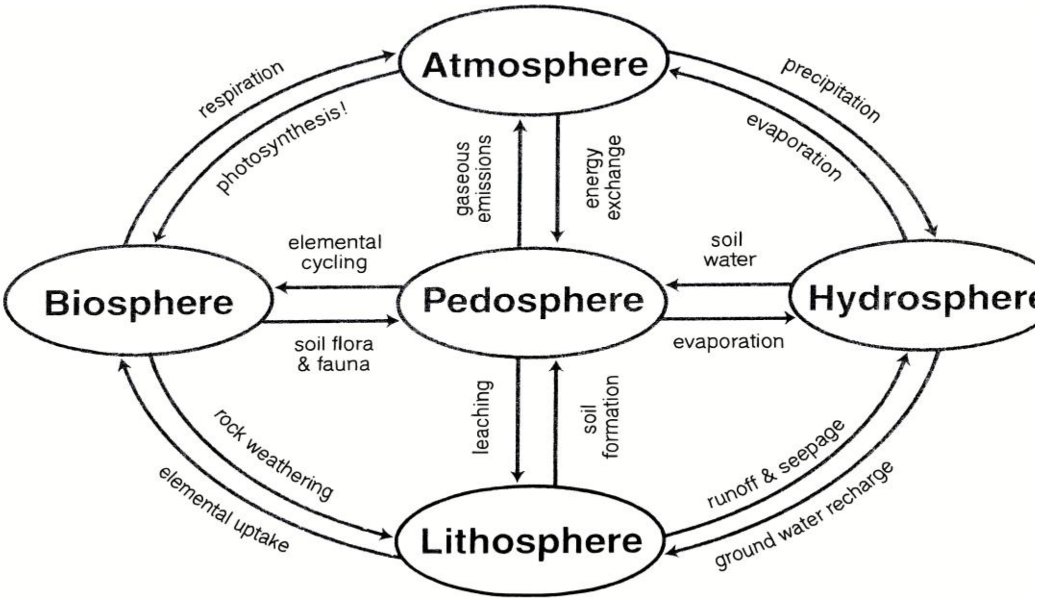

Figure 1

The small print in Figure 1 shows some terms used to describe various interactive processes between the pedosphere (topsoil and subsoil; topsoil may sometimes be as deep as 60 cm, and can be serviceable if it is only some 15 cm deep; subsoil may be anywhere from 60 cm to 6 metres deep), the atmosphere, the

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1. See Sulabha Brahme, *Drought in Maharashtra, 1972: A Case for Irrigation Planning* (Gokhale Inbstitute, Pune, 1983). She points out (p.51) that "The drought of 1972 [also] affected ... Rajasthan, Gujarat, Karnataka and Andhra Pradesh" and that the effect was "quite acute in the Maharashtra State." Mother Nature thus helped to promote intense dissatisfaction with Indira Gandhi's government and hence the "J.P. Movement" of 1974-75, the Emergency of 1975-77, and then the founding in 1977 of the Janata Party and in 1980 of the BJP. Environmental events do sometimes have political effects, and not least in parliamentary democracies. This may become more and more the case in the 21st century.

2. Commissionariate of Agriculture, Maharashtra State, internal "Memorandum on Drought Situation in Rabi 2012 and Mitigation Plan (Revised)" (Pune, February 2013), the tables on p.8, and on p.2 the last line of the table entitled "Progressive Rainfall". ("Rabi" means "after the monsoon".) The tables in this document give somewhat detailed information – about various crops in various districts – which we have synthesized with "overall" figures of 90% for the monsoon (see the last box in Table 1) and 20% down for the crops. We extend thanks to the Commissioner for sharing this document with us.

"biosphere" (an incredible variety of organisms in soils, which have thus been described as "the most complicated biomaterials on the planet"[3]), the hydrosphere (H_2O), and the lithosphere, which is below the subsoil and consists of mainly impermeable rock.

Three terms not mentioned in Figure 1 are "erosion", "aquifers" and "water table". Erosion of topsoil can be caused by wind or water blowing or washing it away if there aren't enough plants etc. to protect and conserve it in place. Aquifers consist of H_2O retained in (*a*) soil and marshes, (*b*) porous rock (i.e. gravel and/or sand) saturated with groundwater, and sometimes also (*c*) underground pools of water, i.e. beneath the soil but above the porous rock.[4] When water comes up from a well, it is from such a pool; whether such pools exist in any particular geographical area depends partly on whether the level of the underground water table there is higher than that of the lithosphere.

The "spheres" referred to in Figure 1 are conceptual abstractions, not spatially distinct orbs; there is, for instance, a lot of H_2O in the atmosphere and in aquifers. Indeed, H_2O is one of the most dynamically renewable of all the renewable natural resources. Many problems are due, however, to mismatches between when and where Nature provides it and when and where we want to have it. Problems also arise when we use H_2O from this or that underground aquifer, lake or river faster than Nature can renew the supply there. This is like dipping into capital for merely ongoing expenses.

Three kinds of factor causing droughts

Agricultural scientists differentiate routinely between three kinds of cause for drought: (*1*) **meteorological**, i.e. due to a lower than historically normal average rate of precipitation for a given geographical area during several consecutive seasons (say, for three, five or seven years); (*2*) **agricultural**, i.e. due to seasonal mismatch between when and where it actually rains and when and where the crops need it; and (*3*) **hydrological**, i.e. due to not enough H_2O being available from reserves in (*a*) the pedosphere (including plant-roots, which store moisture), (*b*) the lithosphere and underground pools, and/or (*c*) man-made storages. (It is noteworthy that giant man-made surface storages – especially the reservoirs behind big dams – are more likely to entail bad social and environmental effects than small storages.[5]) Most droughts are due a combination of hydrological and either meteorological or agricultural causes. It is usually hydrological plus one of the other two.

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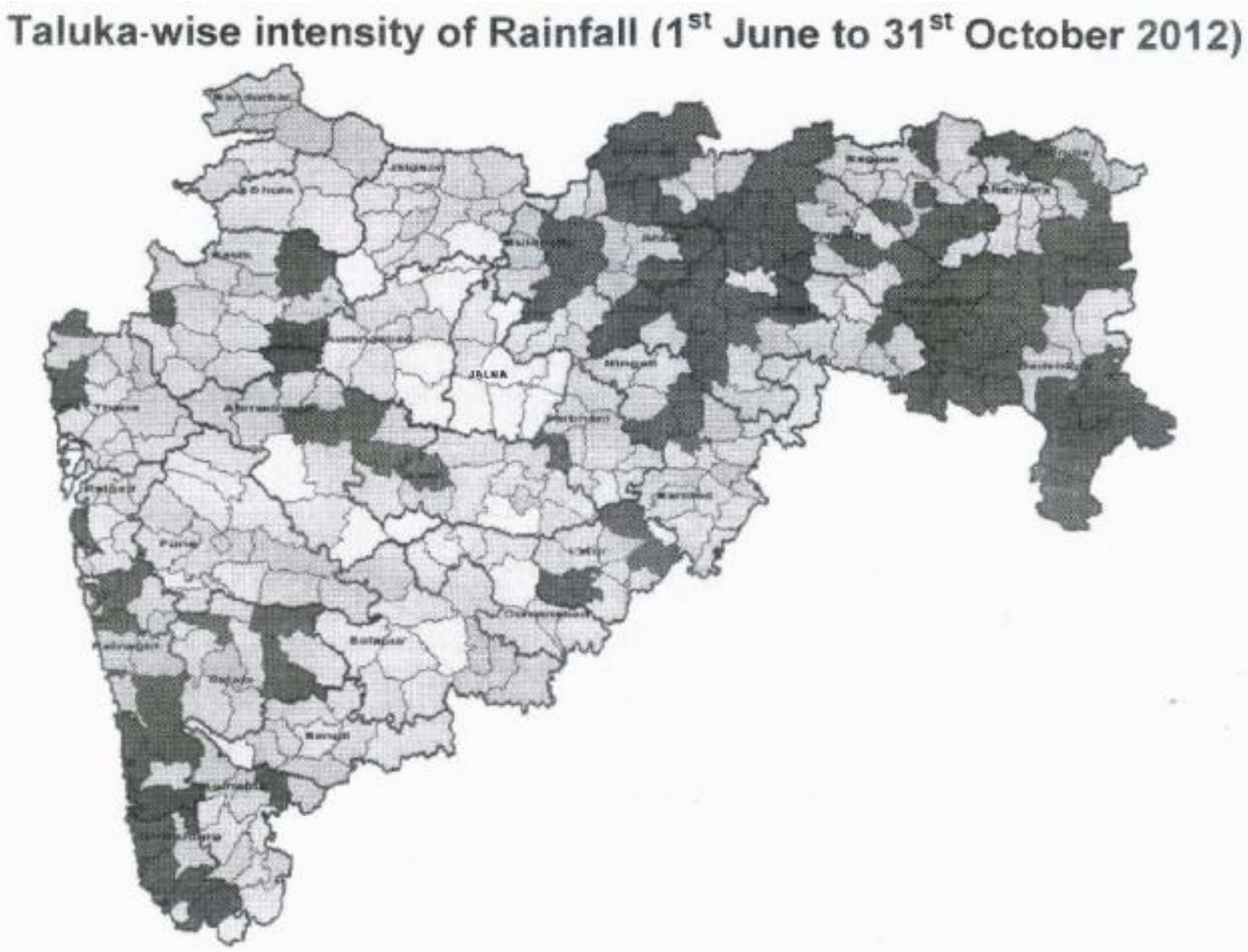
3. I. M. Young and John W. Crawford, "Interactions and Self-Organization in the Soil-Microbe Complex", in *Science*, vol.304 (2004), the first sentence of the abstract; see www.sciencemag.org/content/304/5677/1634.

4. Figure 1 is taken from *Frontiers in Soil Science Research: Report of a Workshop* (National Academies Press, Washington, 2009; see www.nap.edu), p.2. Some good sources of definitions of relevant technical terms are Michael Allaby, ed., *A Dictionary of Ecology* (Oxford University Press, 1994 and later editions) and Charles Park, *A Dictionary of Environment and Conservation* (Oxford Univ. Press, 2007). Gravel is defined as consisting of rocks between 2mm and 75mm in diameter; sand particles are made of the same kinds of minerals but with the diameters of the particles being between 2mm and some lower limit, depending on whose definition of sand you prefer. Sand, however defined, can store vast amounts of water.

5. See for instance R. Rangachari, Nirmal Sangupta, Ramaswamy R. Iyer, Pranab Banjeri and Shekhar Singh, *Large Dams: India's Experience. Final Report: November 2000* (Secretariat of the World Commission on Dams; see http://www.dams.org).



The map shown here indicates the extent to which the drought in 2012 was spatially "agricultural". The unshaded parts of the map represent the talukas where the total amount of rainfall during the five months from June through October was less than half of normal. (A very "dry" area was just about in the middle of the plateau, notably in Jalna District.) The darkest-shaded parts of the map represent talukas where the corresponding total was higher than normal. Table 1 shows that the deficiencies (overall in Maharashtra) were at their worst in June, less bad in July, and so on. Of course if you are a farmer, you care less about

Month	Rainfall (mm)		%
	Normal	Actual	
June 2012	222.1	155.1	69.8
July 2012	390.3	338.9	86.8
Aug 2012	297.6	276.6	92.9
Sept 2012	198.8	214.2	107.8
Oct 2012	64.4	77.0	116.0
June to Oct	1175.4	1061.5	90.3

Table 1[6]

average distributions than you do about the synergies between the rainfall and your own crops; this is why a drought due to poor synergies in this regard (rather than to a basic lack of total rainfall) is called "agricultural".

6. This table and the map are from the report cited above in Note 2.

For each of the three kinds of negative factor that we have mentioned (meterological, "agricultural", hydrological), there is a corresponding positive kind. (*1*) You could improve your meteorological situation by moving to Kerala or Odisha from an arid part of Rajasthan. People do sometimes migrate for that kind of reason. (*2*) A monsoon is good distribution-wise if the rainfall synchronizes with the needs of the crops. (*3*) Hydrological conditions can be improved so much by implementing wise policies that a monsoon 10% weaker than average would have practically no bad agricultural effect at all.

Let us focus now on this vital point that factors not stemming directly or indirectly from human activity can seldom render a drought intense without the help of man-made causes. It explains why the consequences in 2012 were much worse than a 90%-good monsoon would otherwise have caused, and why the sad story is likely to happen again and again until wise policies are effectively implemented.

(*1*) India has been getting, on average in modern times, some 4000 billion cubic metres of water annually from precipitation and snow-melt. That is enough **meteorologically**. Average annual precipitation has been slightly more than a metre per year. Total precipitation for all of India in an average "good year" would be 1.15 metres, in an average bad year, 0.85. (In 2012 it was 0.9.) For seasonal agricultural crops, less than half a metre annually can enable one crop per year to come to fruition[7] if the supplies of H_2O from the lithosphere and biosphere are in reasonably sound condition (which would be the case if our policies were wise).

(*2*) There is, however, some bad news: the year-to-year and region-to-region differences in precipitation – entailing floods as well as droughts – have been getting more pronounced in recent times. This destructive climate change has almost certainly been due the "greenhouse effect" caused by worldwide use of fossil fuels in the 20th century, especially in the West. The glass of a greenhouse lets sunlight pour in freely but to a considerable extent blocks the heat into which some of that light is transformed inside the glasshouse from getting out. Too much carbon dioxide in the atmosphere (due to burning vast amounts of fossil fuels) likewise prevents the heat that is produced by our economic activities and wars from being diffused as quickly into outer space as it would be if there were less carbon dioxide in the air. The resultant "global warming" is not in the core of the globe but in its outer layers, where the weather takes place. This is in two ways a subtle matter, however. On the one hand, the rise in *average* worldwide surface temperature has been, so far, a matter of just one or two degrees centigrade; it is paradoxical that such a subtle average difference can make such a pronounced difference in the weather. On the other hand, this kind of outdoor "greenhouse" effect is due to changes in a tiny share of the atmosphere – so much less than 1% that it is reckoned in terms of parts per million volume-wise. Figure 2 (on the next page) shows scientific estimates for nearly a thousand years from 1000 to 1998 C.E.; the number in 1998 was 365; it has now surpassed 400. Table 2 shows the per-capita amounts (estimated by the World Bank) of "carbon footprint"[8] for India, China, Germany and the USA in 1995 and 2008. If humankind goes on using fossil fuels lavishly, climate change will almost certainly become more and more destructive during the rest of the 21st century.[9] The effect is worse from the burning of coal, which emits smoke as well as carbon dioxide, than from burning petroleum or natural gas. Most of India's consumable energy comes from burning coal. India's and China's current per-capita levels of carbon footprint are still today (in 2013) much lower than the USA's, but India's and China's people together are a third of humankind, whereas the USA's current

7. Most kinds of fruit trees, however, do require more than half a metre annually of rainfall to yield normal harvests.

8. See http://en.wikipedia.org/wiki/Carbon_footprint.

9. See http://en.wikipedia.org/wiki/Physical_impacts_of_climate_change.

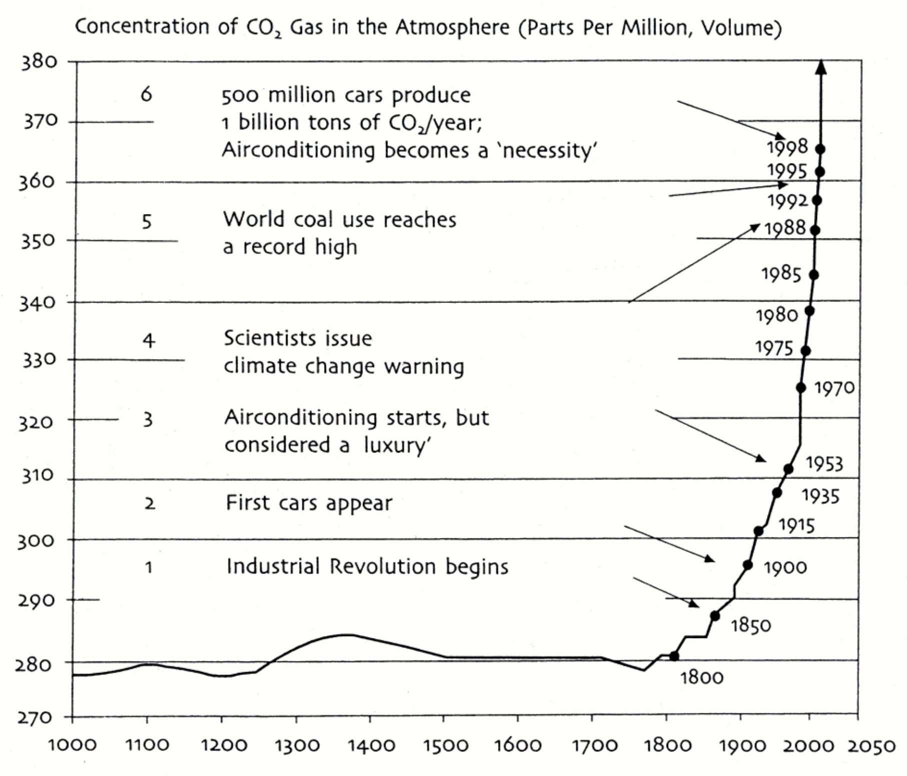


Figure 2 ↑ and *Table 2* ↓

	Tons per capita of carbon footprint ***in 1995***:	***in 2008***:	***Difference***
India	**1.0**	**1.5**	**0.5**
China	**2.8**	**5.3**	**2.5**
Germany	**11.0**	**9.6**	**−1.4**

population (*ca.*315 million) is not much more than a fourth the size of India's or China's (about equal at 1200+ million each). China's total carbon footprint is nowadays as great as the USA's. India ranks just behind them, and is catching up. It is most likely[10] that the result will be, for many years to come, "**agricultural**" causes of drought getting worse and worse.

(*3*) There have meanwhile been big changes in the **hydrological** situation. According to estimates published in 2012,[11] India is currently pumping some 190 cubic kilometres[12] of water a year from underground, while Nature is replenishing only 120 of those 190. About a quarter of India's food-crops are irrigated with underground water which Nature is no longer replacing. Talk about spending capital for current expenses! The water tables in India have been receding in recent years at a rate of one to five metres per year.[13] A few centimetres would be worth mention in a scientific report; one-to-five metres is so much that every economist and politician ought to be thinking and talking about it.

Where has all that water from our aquifers been going? A big part of the answer is: to cities and to certain factories from which it is flushed (together with vast amounts of sewage and other dangerous waste)

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10. There is not 100% scientific certainty about this, but only, say, 98%.

11. See http://news.nationalgeographic.co.in/news/2012/12/121218-grabbing-water-from-future-generations/.

12. A cubic kilometer is nearly 265 billion gallons (equivalent to some 400,000 Olympic-size swimming pools).

13. Marathi daily newspaper *Sakal*, Aurangabad edition, 28 February 2013, p.1.

into rivers carrying it mostly to the oceans because sand mining for the construction of concrete buildings has substantially depleted the capacity of the river beds in India to retain and conserve H_2O. Sand is so good at storing water[14] that the layers of sand along river banks are metaphorically called the lungs of the riverine system. So it is tragic that whereas some 40% of the H_2O from precipitation in India (and in Nepal and Tibet, from which some of India's rivers flow) used to be retained and utilized agriculturally, the portion nowadays is less than 30%. This difference represents a huge loss for the more than 60% of India's crops which get all of their H_2O from the monsoon and none from irrigation. Those are the most nutritious crops, and most of them are grown by poor farmers, who are economically very vulnerable to losses of aquifer capacity.

Long-term damage wrought by the "Green Revolution"

This brings us now to some negative aspects of the Green Revolution which were less evident during the euphoria of its first decades – the 1960s and '70s – than they have meanwhile become. To understand them is part of resource literacy in regard to food; we will now venture slightly into that topic, and then come back to the issue of hydrological droughts.

The defining characteristic of crops is that they are cultivated in fields and gardens. The agronomic term for such domesticated varieties of plants is "cultivars." An important point ignored in Green-Revolution technology is that the genetic make-up (encoded in DNA) of the *traditional* cultivars is due not just to age-old[15] agronomic selection by humankind, but also to the fact that the cultivars have evolved (via genetic mutations) in various diverse agro-climatic conditions peculiar to the specific geographical regions where the evolutions have taken place. These evolutions have involved symbiosis not just between the cultivars and the cultivators (as our teeth and digestive systems have become different from those of our remote ancestors), but also between the cultivars and the other kinds of biota[16] in the soil: microbial flora, worms etc. Local soil and local flora, including the agricultural flora, have evolved *together* over the centuries: the soils in modern agriculture are not from wilderness, but mostly from ancient gardens and fields – and this is certainly the case in Maharashtra.

When a new cultivar is developed in some locality by cross-breeding from two older cultivars native to the local soil, all the adaptive virtues (in relation to that particular kind of soil) of the older varieties are likely to be preserved. But such is not the case when a non-native cultivar is introduced. The biotechnologists of the "Green Revolution" ignored this basic fact. Their quick-fix inventions, mainly developed far away from sites in India,[17] were technologically superficial, yielding an ecologically destructive "boom" of profitable crops (and profitable sale of seeds and artificial fertilizers and pesticides) for a few decades but then leaving India's agriculture in an unprecedentedly vulnerable condition *vis à vis* Mother Nature. The phrase "Mother Nature" evokes gratitude for reliably benign nourishment, but in reality the non-human part of Nature – except maybe for some domesticated animals attached to their owners – doesn't care whether we humans flourish or perish.

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14. The capacity of sand to hold water so well is due to some electro-magnetic aspects of the way in which water occupies the odd little spaces (which would otherwise be occupied by air) between the irregularly shaped grains of sand.

15. This vague expression, "age-old", is used here to mean more than a just a few human life spans (though still far less than an astronomical time span such as would be described in terms of light-years).

16. ("Biota" means "all the living organisms".)

17. See en.wikipedia.org/wiki/Green_Revolution and en.wikipedia.org/wiki/Green_Revolution_in_India.

It would be tempting to wander now into an account of environmental damage due to indiscriminate modern use of artificial fertilizers and pesticides in the wake of the Green Revolution. But let us instead come back to our main topic, droughts in Maharashtra, by pointing out that the new, high-yield varieties of rice, wheat, millet, pulses, cotton etc. which the Green Revolution has bestowed on us are more dependent than the traditional native varieties are on plenty of water being available for agricultural use during a relatively short (for high-yield crops) growing season; and therefore a weak monsoon has a worse effect on those artificial new varieties than on the traditional varieties. And since the traditional varieties are in fact drought-resistant in several ways, a monsoon weak enough to reduce by 80% the productivity of a "high-yield" variety would reduce by only 20% the productivity of a traditional variety. This aspect of the *resilience* of the traditional varieties is due to their having evolved for centuries during which there were poor as well as strong monsoons. Only the genetic strains that withstood the poor monsoons survived.

Alternatives

What could be done to prevent future weak or altogether weird monsoons from devastating Maharashtra's crops?

(*1*) Internationally and nationally: switch from fossil fuels to new, e.g. "solar-energy" sources of consumable energy, so as to stop aggravating the extent to which climate change is rendering monsoons more and more erratic. (It is conceivable, by the way, that global warming might render the plains of Siberia and Sweden more fertile; but it can hardly have such an effect in India.)

(*2*) Nationally: use water much more sparingly and carefully in the cities, and, when irrigating crops in the countryside, do it more efficiently – pumping up less water from below the water-table – by converting from flood-irrigation techniques to water-conserving micro-irrigation methods such as drip, sprinkler and diffuser. (There happen to be some good pre-20th-century drip techniques, such as using earthen pots with holes in the bottoms.)

(*3*) Nationally, and especially in Maharashtra: stop building more big dams. Maharashtra has already 40% of all the big dams in India. The destructive ecological – and social – effects of building more would certainly be, on balance, greater than the benefits (apart from the immediate monetary benefits to the contractors and their mostly low-paid employees and to the bureaucrats and politicians taking bribes in return for sanctioning the projects). The ecological effects include (*a*) the losses – by submersion – of farmland and woodland and (*b*) the losses of sand from river-beds to make the concrete for the dams.

(*4*) In Maharashtra: incentivise farmers to grow traditional varieties of pulses, cereals (including millet, sorghum, ragi and maize as well as paddy) and oil-seeds, rather than sugarcane, soyabeans and other kinds of crops promoted by the Green Revolution.

Sugarcane is a water-guzzling crop (requiring at least 25 million liters per hectare), hydrologically resource-squandering in the Deccan plateau though well suited to the Indo-Gangetic plain where ample rainfall and abundant sources of water for irrigation – thanks to relatively higher water tables there – can support it on a long-term basis. Traditionally small amounts of native sugarcane used to be grown in Maharashtra. Vast amounts of non-native varieties have been cultivated since the Green Revolution (and very profitably, thanks to government subsidies). Soyabeans have in recent decades become commercially profitable for export as poultry- and cattle-feed to countries like China and Japan where people are mostly carnivorous and have been getting more and more cash to spend. But soyabean crops extract nutrients lavishly from the soil. Such crops are well suited to coastal plains where occasional flooding brings in some good mineral micronutrients and helps the resident biological nutrients multiply. We don't have that kind of advantage on the high plateau of Maharashtra.

Grapes, pomegranates and new varieties of bananas are three other kinds of crops which the Green Revolution has promoted in Maharashtra but which are ill-suited to her agricultural resource-endowment. Maharashtra produces nowadays more than half of India's grapes, more than a third of her bananas and more than a quarter of her pomegranates. All three are water-guzzlers (though pomegranates and grapes less than sugarcane; see Table 3).

CROPS	WATER (cm)
Lentils	35
Millet	45
Groundnuts	55
Chillies	75
Wheat	83
Potatoes	105
Cotton	105
Vegetables	113
Onions	128
Sugarcane	415
Bananas	480

Table 3[18]

(Let us note, by the way, that heavy doses of pesticides are sprayed and dusted to protect grapes and pomegranates from vermin, and those pesticides poison the soil and groundwater; that all these non-native crops are nourished, in Green-Revolution technology, by heavy doses of artificial fertilizers; and that the hydrological deficits due to these new crops have led to an unhealthy increase of salinity in the soil: too much salt accumulating because not enough water is rinsing it out.)

(*5*) Rejuvenate the soil aquifers by means of meticulous and systematic micro-watershed management based on the ridge-to-valley principle: On one side of the ridge between two big watersheds, streams (which will combine at a lower level to make rivers) flow down in one general direction, whereas on the other side of the ridge they flow in pretty much the opposite direction. On the way down, and especially near the top, they flow more or less swiftly, depending on the angle and substance of the terrain. (Along the top of the highest ghats near the west coast of South India is a ridge from which relatively short rivers emerge flowing westward down to the Arabian Sea while long rivers emerge flowing eastward toward the Bay of Bengal off the coasts of Andhra Pradesh and Tamil Nadu.) A micro-watershed is a very local part of a big watershed. Good micro-watershed management depends on good local data and consists of artificially reshaping some terrain (this is sometimes a subtle affair) so that the water instead of gushing down swiftly in rivulets will seep through the soil and make an agriculturally useful aquifer. The rule is: Where the water is naturally "running" down, make it "walk" so that it won't cause erosion by taking topsoil with it; where it is naturally "walking" down (which may be closer to the valley than to the ridge), make it pause and seep into the soil. On the plateau of Maharashtra we are never very far from the ridge of the western ghats, and sometimes very near it. To manage properly the micro-watersheds there, we have to know exactly the location of the ridge. Knowing that – and making good use of the knowledge – is a matter of applying the "ridge-to-valley" principle. A motto for this kind of thinking is "Rainfall, Runoff, Recharge", where "rainfall"

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18. This is extracted from a table on p.119 of the book cited above in Note 1.

refers to all kinds of precipitation plus any relevant snow- or ice-melt; "runoff" refers to how the water is proceeding from the ridge to the valley; and "recharge" refers to streams and aquifers benefitting when the runoff is slowed down. If human muscle-power is needed to manage micro-watersheds in keeping with the ridge-to-valley principle, the fiscal resources of the Mahatma Gandhi Guaranteed Rural Employment Act might be drawn upon. If not enough human muscle-power is readily available, the work could be done with animal muscle-power or with machines burning fossil fuels.

(*6*) It would be good to reallocate the uses of various fields in Maharashtra according their long-term-sustainable biotic potentialities. This would entail letting some fields revert to their more traditional uses as pasture (full of grass, with its roots preventing erosion throughout the year by strengthening the soil) and woodland densely enough stocked with trees to enable them to mitigate runoff. Ideally, a third of the land ought to be pasture and woodland. In Maharashtra today, pasture is about 5%, dense woodland less than 2%.

We may conclude by recalling and adapting some expert remarks made by a distinguished American hydrologist, Raymond L. Nace, some 30 years ago:[19] "Three sins beset water planners and their advisers: faith in [superficial] science and technology; worship of bigness; and arrogance towards the landscape. The belief that [certain kinds of] technology [with big profits for big corporations] can solve any water problem is wrong. It seems essential that a new frame of mind ... be applied to water planning."

19. See http://exacteditions.theecologist.org/browse/307/308/6083/3/36. Dr. Nace was a top research hydrologist with the Water Resources Division of the United States Geological Survey.