

## CHAPTER FORTY-FIVE

# Water, Floods, and Aquifer Replenishment

### *PQNK as Hydrological Solution*

*“Across the farmed world, the same land drowns and thirsts. It drowns in the rainy season because its soils cannot absorb the rain. It thirsts in the dry season because it did not capture the rain when it fell. Both are the same problem: a hardpan-sealed, biologically dead soil that repels water rather than receiving it. PQNK does not manage floods. It prevents them. And it does not supply water. It stores it.”*

Asif Sharif, Lahore, 2023

The water crisis is the most acute and most immediate of the seven dimensions of agricultural bankruptcy documented in Chapter Thirteen. Wherever industrial agriculture has hardened the soil, from the plains of South Asia to the irrigated drylands of every continent, three water crises appear together, and they seem contradictory until their common cause is understood: recurring catastrophic floods that destroy lives and infrastructure, chronic droughts and water shortages in the seasons between, and the progressive depletion of the aquifer systems that farming increasingly depends on to bridge the gap between these extremes. Pakistan, the documented case in this chapter, faces all three at once. All three are consequences of the same underlying condition: a sealed, impermeable agricultural landscape that cannot absorb the water it receives.

This chapter makes the case that PQNK’s restoration of soil biological function is not merely an agricultural intervention but a hydrological one, that the transition from ACI management to PQNK management at scale would transform the water situation of Pakistan, and of every country with the same sealed soils, more significantly and more rapidly than any engineering infrastructure programme proposed or under construction.

### THE THREE WATER CRISES AND THEIR COMMON CAUSE

The relationship between these three water crises and the hardpan-sealed agricultural landscape was established in Part One. This section traces the connections in operational terms that allow the policy implications to be calculated.

**The flood crisis.** Heavy seasonal rains fall on agricultural land that cannot absorb them. The hardpan layer, typically 8 to 17 inches below the surface, acts as an impermeable barrier: rain that falls faster than the topsoil can absorb ponds on the surface and then runs off laterally as sheet flow that combines into watercourses, then into rivers, then into the flood events that have devastated Pakistan in multiple catastrophic seasons. The scale of Pakistan’s 2010 and 2022 floods, each affecting tens of millions of people and causing billions of dollars of damage, was amplified by the impermeability of the agricultural landscape through which the rainfall had to travel.

**The drought and water shortage crisis.** Because the same rain runs off rather than infiltrating, the soil moisture reservoir that should sustain crops through the dry months between monsoon events is never filled. Farmers irrigate from rivers and aquifers to compensate for the moisture that the rain delivered but the soil could not retain. The irrigation deficit that results from this failure to retain rainfall is the primary driver of irrigation water demand wherever the soil is sealed, in Pakistan as elsewhere.

**The aquifer depletion crisis.** The irrigation water that compensates for the rainfall the soil could not retain is pumped from aquifers that receive no recharge because the rainfall that should recharge them ran off rather than percolating downward. Worldwide, satellite gravity data from NASA's GRACE mission shows 21 of the world's 37 largest aquifers in deficit, their water tables falling year by year as withdrawal exceeds recharge, and Pakistan's major aquifers are among them. The energy cost of pumping from progressively deeper levels grows with every metre the water table falls. In Punjab, the water table has fallen from an estimated 6 to 10 metres in 1960 to more than 100 to 200 metres in some areas today.

*A sealed landscape loses its rainfall in the same season it falls. The rain arrives as a flood, runs off the sealed surface, and enters the rivers that carry it to the sea. Three months later the farmer is pumping from 100 metres or more to irrigate a crop with water that fell on his field and was rejected by his hardpan. This is not a water shortage. It is a water management failure. And the management failure is in the soil.*

## HOW PQNK SOIL MANAGES WATER: THE PHYSICS

A PQNK soil with fractured hardpan and restored biological pore structure manages water through a fundamentally different physical and biological architecture than a conventionally managed soil.

The water infiltration rate of a biologically active soil with intact aggregate structure and open biopore channels is dramatically higher than a conventionally managed soil. When 13 inches (330 mm) of rain fell in eight hours on Jaskaran Singh's Kinnow orchard in Fazilka district, Indian Punjab, his PQNK beds with the hardpan broken had taken the water into the soil, while the conventional land beside them stood under water (Knowledge Paper KP-213). That difference in infiltration determines whether a given rainfall event enters the soil or runs off it.

Below the surface, the fractured hardpan allows the infiltrated water to continue moving downward through the root channel network and earthworm galleries into the subsoil and eventually to the water table below. This downward movement is what recharges aquifers. On a conventional soil with intact hardpan, the water that does infiltrate pools above the hardpan and either evaporates upward or moves laterally as subsurface flow rather than recharging the aquifer beneath.

**PQNK soil infiltration rate:** 13 inches (330 mm) of rain taken in within eight hours on PQNK beds (KP-213) (vs conventional land beside them under water)

**Rainfall captured per hectare:** rain enters the beds instead of running off (vs ponding and runoff above the hardpan on conventional land)

**Aquifer recharge contribution:** rain moves down through the broken hardpan, and irrigation pumping falls by 77 to 92 percent (Chapter Twenty-Six crop comparisons)

**Soil moisture retention:** mature beds need no irrigation where annual rainfall is 400 mm or more (during transition, furrow water only when the ball test shows a need)

## **PQNK AND FLOOD PREVENTION: THE LANDSCAPE-SCALE ARGUMENT**

The flood prevention argument operates at the landscape scale rather than the individual farm scale. A single PQNK farm that takes its rainfall into the soil rather than running it off removes that farm's rainfall from the surface flow system that feeds flood events. The cumulative effect of millions of PQNK farms in a watershed is the removal of a large fraction of the rainfall from the flood flow system.

Take Pakistan as the case. Its agricultural land covers close to 37 million hectares. If half of this area, the irrigated flatland most affected by hardpan compaction, were managed under PQNK with its documented infiltration improvement, the volume of rainfall entering the surface runoff system in a major monsoon event would be reduced by tens of billions of litres for each significant rainfall event. The hydrological consequence would be measurable in reduced flood peaks in rivers draining the agricultural zone, reduced flood duration, and reduced flood damage to the downstream communities and infrastructure that Pakistan's annual flood bills document in the billions of dollars.

Pakistan's flood damage bill in the 2022 super-flood was estimated at \$30 billion. The 2010 flood caused about \$10 billion. These are not weather events that engineering alone can address: the flood embankments, diversion channels, and reservoir infrastructure that Pakistan, like most countries, has constructed manage the water after it enters the river system. PQNK prevents it from entering the river system by keeping it in the soil where it fell. The infrastructure cost of PQNK transition, the machine subsidy that the policy prescription requires, is a fraction of a single flood season's damage.

## **AQUIFER REPLENISHMENT: WHAT THE WATER TABLE DOES WHEN SOILS ARE OPEN**

The aquifer replenishment argument is the most long-term but ultimately the most consequential of the three water crisis solutions that PQNK offers. Aquifer depletion is a slow emergency: the water table falls a metre or two per year, the pump gets a little more expensive, the energy cost grows a little more burdensome, until the aquifer is too deep to pump economically and the agriculture it sustained becomes impossible.

Where PQNK covers a substantial proportion of the catchment area feeding a shared aquifer, the balance of that aquifer changes. The mechanism is straightforward: more rainfall infiltrates through PQNK soils to the water table below; PQNK farms irrigate less, reducing the withdrawal rate; and the net effect is recharge minus withdrawal shifting from negative to neutral or positive.

The reversal of aquifer depletion is not merely an environmental benefit. It is an economic one: the pumping cost savings from a stable or rising water table compound across every farm in the recharge zone. And the long-term agricultural viability of regions currently facing the prospect of permanent aquifer loss, Balochistan's vegetable districts, Punjab's cotton belt, Sindh's sugarcane zone, depends entirely on whether the withdrawal-to-recharge ratio can be reversed before the aquifer is lost.

*The \$30 billion flood of 2022 was a hardpan event. The water that caused the flood fell on agricultural land. It ran off because the hardpan would not let it in. The cost of subsoiling Pakistan's agricultural hardpan nationally is a fraction of*

*one flood season's damage. The prevention is cheaper than the event. By orders of magnitude.*

## THE DEW AND HUMIDITY HARVEST AT SCALE

Chapter Twenty-Seven described the dew and humidity capture mechanisms of the PQNK mulch layer at the individual farm level. This section considers what those mechanisms mean at landscape scale, when millions of mulch-covered PQNK beds are simultaneously capturing dew and absorbing atmospheric humidity across an agricultural district.

Dew forms when warm, moist air cools below its dew point on contact with a cooler surface. Bare agricultural soil loses its captured dew within an hour of sunrise as the soil surface heats rapidly. The mulch-covered PQNK surface does not heat rapidly because the mulch insulates it: the dew that forms on the mulch fibres is drawn downward by capillary action into the soil rather than evaporating. At a landscape level, a region with millions of mulch-covered PQNK farms is a region that is removing dew moisture from the atmospheric boundary layer and adding it to the soil moisture system rather than returning it to the atmosphere within hours of its deposition. The cumulative dew capture across a large PQNK agricultural region represents a moisture addition to the soil system that has no equivalent in the conventional landscape.

The atmospheric humidity absorption of the mulch surface compounds this effect. A mulch-covered landscape has higher surface roughness than a bare or sparsely vegetated one, providing more surface area for atmospheric moisture absorption. The cumulative effect of this increased surface area across a large PQNK agricultural region is a measurable contribution to the soil moisture balance that is absent from conventional agricultural hydrology.

## WATER SAVINGS AS HYDROLOGICAL POLICY

The crop-specific water savings documented in Chapter Twenty-Six, 81 percent for wheat, 77 percent for cotton, 88 percent for sugarcane, 92 percent for rice, are not merely farm-level economics. At national scale, they represent the single largest reduction in agricultural water demand available to any irrigating nation achievable without reducing crop production.

In Pakistan, total agricultural water withdrawal is approximately 170 billion cubic metres per year, more than 90 percent of total national water use. An average 80 percent reduction in irrigation water across Pakistan's irrigated crop area would represent a reduction of approximately 136 billion cubic metres per year in agricultural water demand. This volume is roughly three-quarters of the average annual flow of the Indus River system. Freed from agricultural demand, this water would flow to recharge aquifers, sustain wetlands, and reduce the salinity intrusion into the Indus delta that is progressively destroying one of Pakistan's most ecologically significant coastal zones.

The water savings of PQNK transition are therefore simultaneously a farm-level economic benefit, an aquifer replenishment mechanism, a flood mitigation tool, a salinity management strategy, and a delta restoration programme. They all derive from the same action: removing the hardpan and restoring the soil biology that the natural water cycle depends on.

## **PQNK AND THE CLIMATE ADAPTATION IMPERATIVE**

The climate risks facing agriculture worldwide are precisely the risks that PQNK addresses: increased rainfall variability (more intense rain events interspersed with longer dry periods), glacier and snowpack retreat reducing dry-season river flows, and rising temperatures increasing evapotranspiration demand from crops and reducing aquifer recharge from winter snowpack. Pakistan, ranked by the Global Climate Risk Index among the ten countries most affected by extreme weather, faces all of them, its dry-season rivers fed by the retreating glaciers of the Himalayan headwaters.

A PQNK agricultural landscape is specifically adapted to these risks: the higher infiltration rate handles more intense rain events without runoff or flooding; the improved water storage capacity extends the period between rainfall and irrigation requirement, reducing dependence on glacier-fed river flows; and the mulch-covered soil surface reduces evaporative demand significantly below the conventional baseline, partially compensating for the increased temperature-driven evapotranspiration. PQNK is not merely a sustainable farming system. It is a climate adaptation strategy whose primary implementation mechanism is the farmer's own decision to follow eight steps on their land.

## **WHAT THIS CHAPTER HAS ESTABLISHED**

PQNK's water transformation is threefold and operates at three scales simultaneously. At the farm scale: 77 to 92 percent irrigation reduction, rain taken into the soil and held there, and soil moisture management that makes the farmer independent of the irrigation calendar. At the watershed scale: flood peak reduction through infiltration, aquifer recharge through percolation, and dew and humidity capture that add to the soil moisture budget without any engineering intervention. At the national scale, in Pakistan's case: a potential reduction of 136 billion cubic metres in annual agricultural water demand, roughly three-quarters of the average annual flow of the Indus River system.

The next chapter considers the atmospheric dimension of PQNK's water impact: carbon sequestration in restored soils, the broken atmospheric water cycle and how PQNK repairs it, and PQNK's position in the global climate response.



*Chapter Forty-Six: Climate, Carbon, and Atmospheric Water, PQNK as Climate Solution*