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Commentary Article

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Bridging the Gap: Rethinking Scale and Biochar

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ABSTRACT

As the world races to address climate change, biochar has emerged as a promising solution one that sequesters carbon (slowing climate change), enriches soils, and supports sustainable agriculture. Yet, a troubling disconnect has taken root within the movement: the relentless push for scalability (scale being necessary to meet our climate needs) that often sidelines the very people who could benefit most from it smallholder farmers.

Large-scale biochar and other carbon capture facilities are becoming the norm, aiming to produce vast quantities of biochar and slow climate change with reduced costs and industrial efficiency. While these centralized operations offer the promise of climate impact at scale, they frequently do so by minimizing or even eliminating the role of local, small-scale producers. In doing so, they risk reinforcing the very inequities that sustainable development seeks to resolve.

This growing divide between top-down expansion and grassroots relevance is more than a strategic misstep it's a critical oversight that could hinder the long-term success and equitable distribution of biochar's benefits and biochar's very acceptance.

Keywords: Biochar, Smallholder Farmers, Centralized Production, Climate Change

Why Smallholder Inclusion Matters Perhaps as Much as 80% of the Southern Food Supply

Smallholder farmers are not just participants in the global food system; they are its foundation. According to the Food and Agriculture Organization (FAO), smallholders produce roughly one-third of the world's food supply and sustain rural economies across the Global South. Smallholders' knowledge, labor, and relationship to the land are essential to sustainable development. Yet they are often excluded from high-level planning and technological innovation in agricultural sectors including biochar.

The marginalization of these farmers in large-scale biochar initiatives has key consequences. It weakens the potential for localized innovation and the diffusion of biochar practices tailored to regional conditions. Specifically, smallholders also possess a nuanced understanding of their soils, crops, and climate knowledge that is crucial in making biochar both effective and sustainable in practice. Ignoring their input risks promoting a generic, one-size-fits-all solution that may fail to meet the needs of diverse environments.

Such exclusion fosters disconnection and disempowerment, too. When sustainable solutions are designed and delivered from afar, they lose legitimacy at the local level. Community buy-in is essential for long-term success; without it, even the most scientifically sound initiatives are unlikely to take root. Scalable solutions must be designed with not just for those on the front lines of agricultural adaptation.

The Pitfalls of Centralized Production

The allure of centralized, mechanized biochar production is

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understandable. It offers economies of scale, access to advanced technologies, and streamlined distribution. But such facilities often operate in isolation from the communities most impacted by land degradation and climate instability. Their design seldom includes mechanisms for local engagement or feedback.

Moreover, industrial-scale biochar production may fail to account for the heterogeneity of soil conditions and farming systems across regions. For example, the biochar formulation suitable for acidic soils in sub-Saharan Africa may not perform well in the loamy soils of Southeast Asia or the sandy soils of Latin America. These differences matter. Without localized adaptation, biochar may be ineffective or even harmful, potentially deterring future adoption.

This highlights a broader issue: scalability, in its current framing, is too often equated with size and output rather than adaptability and reach. True scalability should mean the ability of a solution to be replicated, adapted, and embraced across varied local contexts. That kind of scaling requires more than machines it demands trust, participation, and co-creation.

Building Inclusive Biochar Systems

To make biochar a tool for both climate resilience and community empowerment, we must refocus our approach to production and dissemination. Central to this effort is the involvement of smallholder farmers at every stage from design to implementation.

One critical step is expanding access to low-cost, appropriate technologies that enable local production. Traditional or modified kilns, for instance, can allow farmers to convert agricultural waste into biochar using methods that are both sustainable and economically viable and thus avert the consequences of their inevitable open field burning. When paired with hands-on training, these technologies not only boost productivity but also enhance soil health and carbon sequestration on a local scale.

Capacity-building programs are equally essential. Through targeted education and outreach, farmers can learn how to integrate biochar into their existing agricultural practices. This empowers them not only to adopt (a technology) but to adapt and innovate with it. In doing so, smallholders may become not just users of biochar, but stewards and advocates for its sustainable application.

Beyond direct support, fostering partnerships between large-scale producers and local communities can bridge this divide. For instance, centralized facilities might source biomass feedstock from smallholder farms, creating new revenue streams and supply chain linkages. , They between could offer training, resources, or even revenue-sharing models that promote equitable benefit distribution. Such hybrid models blending top-down investment with bottom-up participation hold the potential to make biochar both scalable and inclusive.

Responding to Urgent Needs

While long-term systems change is crucial, the immediate needs of smallholder farmers cannot be overlooked because there are so many of them in peril today. Climate change is not a distant threat for these communities it is a daily reality. Prolonged droughts, erratic rainfall, and declining soil fertility are already undermining food security and livelihoods. Biochar offers a partial remedy, but only if it is accessible today.

Simple application production methods, such as pit kilns or top-lit updraft (TLUD) stoves, can be disseminated now to help farmers retain soil nutrients, reduce fertilizer costs, and improve crop yields. These low-tech solutions require minimal investment but offer substantial returns when matched with many local.

Governments and development agencies have a role to play here, too. Public policies and funding mechanisms must prioritize grassroots innovation, not just industrial scaling. Grants, subsidies, and technical support for community-led biochar projects can stimulate local economies while promoting climate-smart agriculture. Equally important is the inclusion of smallholder voices in biochar policy forums, research initiatives, and market development strategies. Their perspectives are not a luxury they are a necessity for grounded, effective action.

Toward a Broader Vision

If biochar is to live up to its potential as a climate mitigation tool, it must serve global, national and local interests. Achieving that balance means rethinking what it means to "scale up." It means valuing inclusion as much as innovation and placing community needs at the center of climate solutions.

This is not a zero-sum choice between industrial efficiency and grassroots empowerment. Rather, it is a call for collaboration among scientists, politicians and farmers, corporations and cooperatives, policymakers and practitioners. The most resilient systems are those that draw on diverse inputs and distribute benefits equitably. Biochar can be such a system, but only if built that way.

In a world increasingly defined by inequality and environmental stress, the future of biochar depends not just on how much we produce, but on who gets to participate. If we hope to create sustainable change, we must ensure that those most affected by ecological degradation i.e. smallholder farmers are not just passive recipients but active architects of the biochar revolution.

Conclusion: Cultivating a Shared Future

The push for scale in biochar production is not inherently misguided but it cannot come at the cost of community engagement and local relevance. In our rush to industrialize, we risk leaving behind the very people who stand to benefit the most. The path forward requires a more nuanced approach, one that blends the power of large-scale infrastructure with the ingenuity and commitment of smallholder farmers.

Ultimately, climate solutions must be rooted in the communities

they seek to serve. This means investing in education, access to technology, and local partnerships that place smallholders at the heart of the biochar ecosystem. The stakes are high, and time is short but by working together across scales and sectors, we can build a biochar movement that is not only effective but equitable.

It is a shared responsibility one that demands respect for those who have long tended the land. Only then can we realize the full promise of biochar: a solution that heals the earth while empowering all those who call it home.