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Making genome editing a success story in Africa

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Since the development of CRISPR–Cas as a tool for targeted genome manipulation in 2012, genome editing has revolutionized basic and translational research around the globe[1]. The technology and its potential in bio-innovation were recently highlighted with the approval of the first CRISPR–Cas-based gene therapies for sickle cell anemia and β-thalassemia in humans. However, genome editing is currently underexplored in Africa, where it could be transformative in addressing key challenges in major sectors (including agriculture, public health and medicine)[2] (Fig. 1).

Similar to other biotechnologies, genome editing faces substantial obstacles in Africa. These include regulatory uncertainty, limited access to laboratories, equipment and reagents for molecular biology work, a shortage of trained professionals, and a low rate of returnees among the diaspora. There is also little investment: most countries devote less than 1% of their gross domestic product (GDP) to research and development. The dependency of African institutions on external funding, unequal collaborations with the Global North and control of intellectual property and licensing by foreign entities further hinder progress. Additionally, there are low levels of integration of biotechnology in school and university curricula, inaccurate risk perceptions and apparent low levels of public support (often due to misinformation), and, as a consequence, inadequate political will.

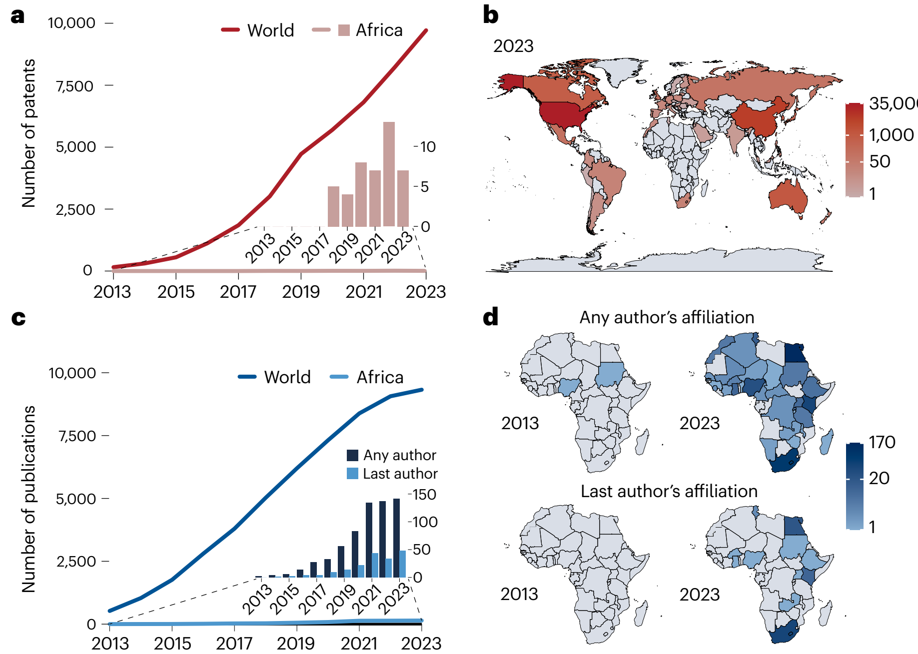

Fig. 1 | Genome-engineering patent and publication distribution. a, Number of patents worldwide (excluding Africa) and in Africa that mention genome editing-related keywords in the years 2013–2023 (data from Patent Lens). **b**, Global distribution of data in **a** for the year 2023. **c**, Total number of scientific publications listed in PubMed that mention 'genome editing', 'CRISPR' or 'genome engineering' in the years 2013–2023 (World) and those with African affiliation (Africa). Inset shows authorship position for African authors in these publications. **d**, Map of author affiliations of African publications in **c**.

The potential of genome-editing innovations in Africa

Genome editing, in contrast to more classical genetic modification approaches, promises greater accuracy, precision, efficiency and cost-effectiveness and, in turn, a better return on investment. In resource-constrained environments, reducing barriers to the genetics-based innovation offered by genome editing could enable local innovators to be more successful in sectors that are crucial for Africa's biotechnology-based economic development. In addition, genome editing-based health products — including novel gene therapies — can have a notable effect on public health.

On the African continent, agriculture contributes up to 35% of GDP and employs more people than any other sector. The local production of crops and livestock is an essential economic activity in guaranteeing food security. Nevertheless, the continent is still heavily dependent on food imports, as environmentally sustainable and economically scalable growth is hindered by supply chain issues, the limited use of modern breeding techniques and a lack of strategies to improve the productivity of small-scale farmers. Facing these challenges, African scientists are eager to leverage the advances that genome editing offers to make tailored solutions for crop and livestock production constraints. For instance, Kenyan and Ethiopian scientists have partnered with Corteva Agriscience to develop genome-edited sorghum to manage one of the most intractable problems of African agriculture, the parasitic plant *Striga*[3]. Other initiatives such as the International Institute of Tropical Agriculture (IITA) are developing genome-edited bananas with resistance to bacterial and viral diseases[4]. In addition, genome editing promises major advances in hybrid development. Hybrid rice, for example, can increase grain yield by at least 40%, but its development using conventional breeding approaches is lengthy and inefficient — a problem that can be efficiently solved using genome editing[5].

In livestock management, genome editing is used to develop live-attenuated vaccines against several diseases. Scientists at the International Livestock Research Institute (ILRI) in Kenya have used CRISPR–Cas9 technology to generate vaccine candidates against African swine fever, a highly contagious viral disease of pigs (whose mortality rate can reach 100%)[6]. Genome editing-assisted precision breeding offers the opportunity to generate livestock that can thrive in the harsh climates that are characteristic of many regions in Africa (for example, through the development of heat-tolerant cattle). Moreover, such breeding might mitigate the environmental impact of livestock farming by modifying the gut microbiome of ruminant animals to reduce methane emissions.

In the public health sector, Africa is confronted with a substantial burden of endemic tropical diseases that encounter weak health systems, underlined by poverty. Ninety-five per cent of malaria cases worldwide are found on the continent, and result in more than 550,000 deaths annually. Other mosquito-borne arboviruses such as dengue further exacerbate the overall disease burden. The control of arthropod vectors of human and animal pathogens through insecticides has led to large gains in disease control[7]. However, the emergence of genetic resistance to insecticides, and its rapid selection and spread in the field, compromise these gains. Using genome editing to detect and study alleles under selection could provide insights into resistance mechanisms, enable molecular screening to detect resistance emergence, establish the risk of cross-resistance between different insecticide classes, and consequently improve strategies for vector control[8]. It is essential that such know-how and technical capacity exists within the countries affected and that this information feeds into national disease control programs.

Advances in mRNA genetic engineering and lipid nanoparticle technologies have had transformative power for vaccines (for example, in the global response to COVID-19) and raised new hope in the fight against malaria. For viral infections that cause serious public health problems in sub-Saharan Africa, genome editing could be used as an alternative to current antivirals[9]. Some preclinical work aimed at using targeted mutagenesis to disable hepatitis B virus (HBV) replication permanently has been carried out in Africa[10]. Therapy based on this approach has an advantage over currently licensed HBV drugs, which largely suppress viral replication without achieving a cure. Genome editing can also be used to study the functional effect of disease-causing gene variants that have not previously been discovered in sequencing data from non-African populations or to uncover novel genetic resistance loci[11], as well as for early disease detection.

Overcoming roadblocks for genome editing-based innovation in Africa

Mistrust surrounding genetic engineering — fed by ethical concerns, fears of unintended consequences and a lack of transparency in communication — hinders its widespread acceptance and implementation. Integrated communication strategies should be developed by governments, regulators and research institutes that build trust through proactive engagement and guarantee well-informed decision-making. Scientists, educators, policymakers and stakeholders must explain, in open and accessible dialog, the scientific principles, potential benefits and risks associated with genome editing. This requires cultural sensitivity, acknowledgment of historical legacies, equitable access, robust public and community engagement, educational initiatives, and international collaboration. A special focus should be put on developing products with clear benefits to the end-consumer and a greater contribution of local scientists could ease misinformation concerns about the ill intentions of foreign agents.

Genome editing is a form of genetic engineering and therefore is inextricably associated with genetically modified organisms (GMOs). Established GMO regulatory frameworks are therefore logical departure points when contemplating genome-editing governance. However, in contrast to when these frameworks were first defined, current frames have established legal and political precedents that do not always align with scientific definitions and interpretations. Genome editing can yield a wide variety of possible products. The question of whether these products are 'genetically modified' or not (and as a result, regulated as such) is complex. Outdated, binary 'GMO or not' regulations should be replaced to accommodate this increased diversity. To do so effectively, explicit product-based regulatory frameworks that distinguish between organisms that contain novel combinations of DNA (trans-DNA sequences) and those that do not should be established[12].

Globally, the great majority of territories (33 out of 35) that have established genome-editing regulatory frameworks allow for this distinction. In Africa, only South Africa currently regulates all genome-editing products as GMOs. The status of genome-editing regulatory practices and discussions in other African countries are diverse (Fig. 2). Argentina — the first country to publish its genome-editing regulations, in 2015 — has already shown how the accessibility of these techniques has stimulated genetics-based innovation by public research institutions and small enterprises[13]. Africa should strive for regional integration and harmonization through pan-African entities such as Africa Centers for Disease Control and Prevention (CDC) or New Partnership for Africa's Development (NEPAD) to enable the resolution of continental challenges across all relevant sectors.

Creating minimal functional units for genome editing in African laboratories is essential for its success. Taking advantage of the low local costs of skilled labor, multiuse resources and redundancies will keep expenses low and promote independence from international supply chains. Local genome-editing resources should allow the testing of novel African-specific (disease-associated) genetic loci — identified through vast genomics efforts — in functional experiments on-site. Funds allocated for establishing suitable infrastructures for projects such as the World Health Organization vaccine program and Genomics Centers of Excellence on the African continent[14] have to be employed to enable the use of genome-editing technologies in the same facilities. This would also put African genomic information in the hands of the local researchers for follow-up studies. What is true for human data should also be applied to biodiversity and agriculture, for which several projects (for example, the African BioGenome project) aim to capitalize on genetic diversity in Africa[15]. These efforts represent a unique opportunity for genome editing on the continent. It is time to connect sequencing and genome-editing projects on-site to establish local research pipelines for data analysis, functional analysis and commercialization.

Private and public funding can guarantee the successful implementation of genome editing-based technologies in African life-science research and development. Along this line, the African Union Development Agency (AUDA-NEPAD) has identified genome-editing research as a key goal in its 'Science and Innovation Strategy for Africa' (STISA 2024) and for the first 10 years of the African Union Agenda 2063. The Genome Editing Technology Initiatives (GETI) from the Network of African Science Academies (NASAC) and Africa Harvest aim to anchor genome-editing technology in the African research portfolio. To make these initiatives successful, African governments must keep their commitment to allocate at least 1% of their GDP to support research. This could result in African Centers of Excellence in genome-editing research in strategic locations that take advantage of existing trade or regional blocs in the continent. Academic research grant themes should not only cover

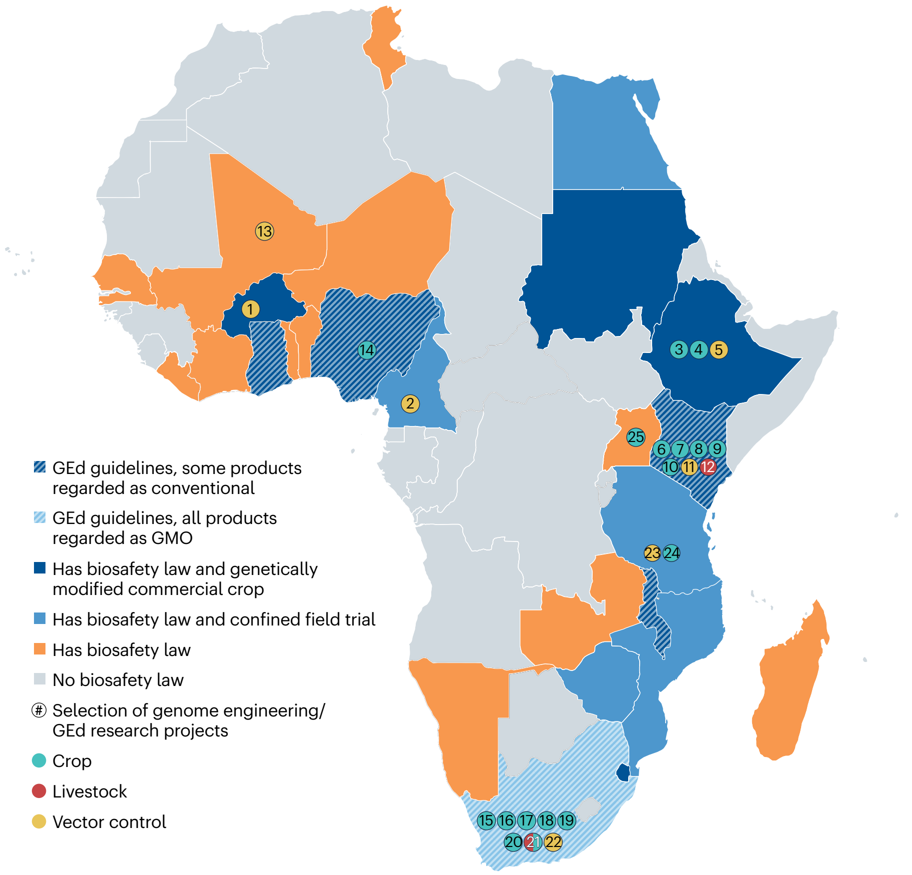

Fig. 2 | African biosafety regulatory frameworks and selected genetic-engineering or genome-editing projects. Numbers refer to project identifiers in Supplementary Table 1, which provides further details of the specific projects. GEd, genome editing.

individual projects but also promote the formation of national research consortia that bring together academic institutions, private companies and government agencies. These collaborative efforts can streamline research lines, share resources and collectively secure funding for large-scale genome-editing projects with substantial societal impact. Equally, African governments' support to research institutes and universities should include a commitment to uninterrupted procurement and maintenance systems that suit the unique characteristics of laboratory-based research.

In addition, African governments must aim to engage public–private partnerships to cofinance genome-editing projects. These collaborations can bring together government funding, private sector investments and philanthropic contributions to create a sustainable and diversified funding model. This involves facilitating partnerships between successful gene-editing companies in the Global North with entrepreneurs in Africa. Tax incentives and regulatory frameworks should aim to attract venture capital investments in genome editing-based startups. Combined with further financial incentives to encourage private investors in the life sciences sector, this should foster the establishment of local biotechnology and pharmaceutical companies. These home-grown initiatives will be critical for establishing a technology-friendly ecosystem and fit-for-purpose commercialization models. Importantly, intellectual property protection and licensing frameworks must be put in place to make the commercialization of genome-editing products sustainable.

One of the most important elements to the success of genome-editing initiatives in Africa is the creation of a critical mass of local scientists with up-to-date practical expertise. These scientists, acting as catalysts, can teach colleagues, advise governments and spearhead knowledge and technological development. Training initiatives in genome editing or existing African–European partnerships remain scattered and sparse. Therefore, sustainable and scalable training programs are needed (for example, TReND in Africa).

Local universities and research institutions should offer theoretical and practical training in molecular biology and genome-editing techniques to provide a sound basis at the undergraduate level. Training at the graduate level should occur within international networks for knowledge and expertise exchange. Successful initiatives should aim for scalability through standardization of operating procedures, manuals and workflows which can be shared for replication at any facility with minimal infrastructure requirements. Candidate selection must be rigid, but once selected, trainees should receive continuous mentoring — ideally combined with small, allocated budgets to initiate independent research in partnership with an established expert at a regional center of excellence. This would also help to prevent emigration of trained personnel searching for opportunities elsewhere, as trainees are incorporated into local infrastructures early and with a clear perspective for future employment. Moreover, incentives for African scientists with expertise in genome editing — ideally equipped with independent funding — to return to Africa should be provided to ensure smooth technology transfer.

Highly trained scientists need adequate time and space to perform research. Governments and universities must develop formats that enable 'protected research time' for faculty members engaged in active research programs and should put in place incentive mechanisms for senior researchers in the field. In the long term, these investments will pay off if highly skilled experts share their knowledge with their peers and help to train the next generation of scientists.

Overall, we envision that if our recommendations are followed and key investments are made in public engagement, regulation, funding and capacity building in infrastructure and human capital, the next generation of genome-editing innovations will come from inventors in Africa. Genome-editing products that are locally developed will help to address the Sustainable Development Goals and improve livelihoods and prosperity on the continent.

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Author contributions

M.C.S. and T.O.A. analyzed data and prepared figures. E.C., V.D.D. and T.O.A. conceived the project and organized the consortium. All authors contributed to the content and read and approved the final version of the manuscript. Authors are listed in the author list in alphabetical order.

Competing interests

V.D.D. is an employee of ZeClinics SL, offering services including genome editing. ZeClinics had no influence on the content of this article. All other authors declare no competing interests.

Additional information

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