

Methodological Challenges in Enumerating Nomadic Populations in Somalia

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Abstract

Accurate enumeration of nomadic pastoralist populations poses significant challenges in censuses and household surveys, especially in contexts like Somalia, where these communities play a vital role in livelihoods and the economy yet remain underrepresented in traditional censuses and household surveys. Methodological obstacles such as their high seasonal mobility, temporary and dispersed settlements, insecurity, and limited interactions with formal administrative systems hinder effective data collection. The paper critically assesses common enumeration strategies, including water point and clan-based methods, identifying their operational strengths alongside inherent biases and coverage issues. To address these limitations, it proposes the Temporary Nomadic Settlement (TNS) approach, which focuses on the actual locations of nomadic households and incorporates Nomadic Link-Workers to provide assistance in real-time data collection and foster community trust. TNS can be implemented through a dynamic sampling frame and a robust two-stage cluster sampling design, where primary sampling units are determined based on probability proportional to size, and households are selected via rapid micro-listing and random sampling. The paper also discusses strategies to overcome challenges like settlement mobility, including immediate listing at settlement levels and the use of satellite imagery and machine learning for tracking movements. Ultimately, while no singular method can completely resolve the difficulties of enumerating nomadic populations, the TNS framework offers a practical and statistically valid solution that enhances coverage and representativeness, thereby facilitating the inclusion of nomadic pastoralists in national demographic and health statistics, which is crucial for equitable policy planning and humanitarian response in Somalia.

Keywords: Temporary Nomadic Settlement (TNS); nomadic population enumeration; Somalia; pastoral mobility; probability sampling

1. Introduction

The Horn of Africa, and Somalia in particular, is characterized by a substantial population engaged in nomadic pastoralism, a livelihood system intrinsically linked to the seasonal movement of livestock in search of water and pasture. Pastoralism is widely practiced in arid and semi-arid lands and constitutes the primary means of livelihood for an estimated 268 million people across Africa [1]. In Somalia, a large proportion of the population depends on livestock rearing, moving with their animals from place to place to sustain their herds.

The total number of nomads in Somalia is not known with any degree of confidence. Still, it has been estimated at roughly 26% of the total population, with estimates varying slightly depending on the source. The nomadic household is defined as a household that normally stays in a temporary nomadic settlement, or in other words, has no permanent place of residence anywhere [2]. Nomadic people move from place to place rather than living in one place all the time and relying on livestock. Nomads are very dynamic, especially during the dry seasons. It has been challenging to accurately locate and record

information about Nomadic households in surveys or censuses due to known factors, including their high mobility over remote terrain.

The livestock kept by Somali nomadic pastoralists commonly include sheep, goats, cattle, camels, donkeys, and horses, reflecting both ecological conditions and long-standing cultural practices.

Pastoral mobility is largely driven by the availability and quality of fodder and water, resulting in pronounced spatial and temporal variability in migration patterns across landscapes [3], [4]. While this non-sedentary lifestyle represents an effective adaptive strategy to environmental variability and climatic stress, heavy dependence on natural resources also contributes to the risk-averse nature of pastoralism [1]. Nomadic pastoralists (NPs) are therefore a vital component of Somalia's socio-economic fabric, underpinning food security, livelihoods, and national economic activity.

Despite their importance, Somali nomadic pastoralists remain among the most difficult populations globally to enumerate and study. Their high mobility, dispersed settlement patterns, and limited interaction with formal administrative systems pose significant challenges to accurate data collection. These challenges are further compounded by insecurity and logistical constraints in many pastoral regions. As a result, substantial data gaps persist, constraining the ability of government institutions, humanitarian agencies, and researchers to design effective interventions, monitor health and development indicators, and deliver timely assistance during shocks and crises [5], [6].

Conventional sampling methodologies that rely on fixed sampling frames—such as census enumeration areas or static household listings—are fundamentally ill-suited to populations whose locations are fluid and often unpredictable. This paper addresses this critical methodological gap by examining the limitations of traditional counting approaches in the Somali pastoral context and proposing adaptive, context-specific strategies to improve data accuracy and representativeness. Emphasis is placed on innovative approaches that integrate technology, local knowledge, and tailored survey designs to overcome the challenges posed by mobility, inaccessibility, and insecurity [7]-[9].

2. Background of Somali Nomadic Enumeration

In Somalia, efforts to enumerate nomadic populations have historically relied on methods tailored to the mobile nature of pastoral livelihoods. The 1975 Somalia Population and Housing Census, enumeration teams were deployed to watering points at the height of the dry season to count nomads arriving to water their animals. This methodology, known as the Water Point Approach. Years later, the 2014 Population Estimation Survey of Somalia (PESS) used this same "Water Point Approach" as its main method to count nomadic groups. Firstly, all water points in the country were listed to create a sample frame, then interviewers were placed at each selected water point, and households arriving to water their animals during the period of enumeration were included in the study. This method assumes that nomadic households and their livestock periodically converge at known water sources, making these points suitable locations for counting people and animals. Similar approaches have also been applied in other pastoral contexts, including the enumeration of nomadic livestock in Mali [2], [10].

Despite its operational simplicity, the water point approach has significant limitations. Subsequent assessments revealed that a considerable proportion of nomadic households do not regularly visit communal water points. Instead, many pastoralists transport water to their herds grazing in remote areas, rely on private or temporary wells, or construct water storage facilities within their localities. These practices are most common during the peak of the dry season, when the availability of pasture and water declines significantly in many regions. To cope with these conditions, pastoralist communities relocate to areas with abundant grazing resources, where livestock can access sufficient forage to sustain their health, productivity, and survival until more favorable conditions return. Consequently, reliance on water points as enumeration sites can lead to systematic undercounting and biased population estimates, as households that remain distant from these points are effectively excluded from the sampling frame.

Beyond water-based methods, several countries with nomadic populations have experimented with alternative enumeration strategies. One such method is the social structure or clan-based approach, which leverages the strong tribal and clan organization characteristic of many pastoral societies. Under this approach, clan or group leaders are engaged to provide lists of households or members belonging to their social units. Enumerators then use this information to identify, locate, and count nomadic households at their temporary settlements. This method has been applied, for example, in the Afar region of Ethiopia during livestock enumeration exercises, where social hierarchies and clan affiliations offered a practical entry point for reaching mobile populations that are otherwise difficult to track.

While the clan-based approach can improve access and community acceptance, it is not without drawbacks. The accuracy of the data is highly dependent on the reliability and objectivity of information provided by clan leaders. There is a risk of intentional or unintentional exaggeration of clan size, particularly in contexts where population figures are linked to political representation, resource allocation, or aid distribution. Such incentives can introduce systematic bias and compromise the validity of the resulting estimates if not carefully controlled through verification mechanisms.

Another method employed in parts of Africa, notably in Mali, is the assembly point approach. This strategy involves identifying locations or occasions where nomadic groups are likely to gather temporarily, such as markets, vaccination campaigns, livestock sales, or seasonal events. Enumerators conduct counts at these assembly points within a defined time window. Although this approach can be cost-effective and logistically feasible, it shares similar limitations with the water point method, as it captures only those households that attend the identified gatherings. Households that are more isolated, security-constrained, or strategically avoiding such points remain underrepresented. Taken together, these experiences demonstrate that no single method is sufficient to comprehensively enumerate nomadic populations. Each approach—water points, clan-based listing, or assembly points—offers practical advantages but also introduces specific biases. This underscores the need for hybrid and adaptive methodologies that combine multiple approaches, incorporate seasonal and spatial variability, and apply validation techniques to improve coverage and accuracy when estimating nomadic populations [11].

3. Alternative Method for Enumerating Nomadic Populations: The Temporary Nomadic Settlement (TNS) Approach

The Temporary Nomadic Settlement (TNS) approach represents an innovative and context-sensitive alternative for enumerating nomadic populations, specifically designed to address the limitations of conventional and semi-conventional methods such as water point, assembly point, and clan-based approaches. At its core, the TNS approach shifts the unit of observation from fixed infrastructure or social aggregation points to the *actual temporary settlements* where nomadic households reside at a given point in time.

A defining and unique feature of the TNS approach is the systematic deployment of Nomadic Link-Workers. These link-workers are typically residents of nearby rural villages or individuals with strong social ties to pastoral communities. Due to their familiarity with local geography, seasonal migration routes, and clan networks, they possess real-time knowledge of the whereabouts of nomadic households within and around a district. Before the arrival of survey listers and enumerators, Nomadic Link-Workers can be contacted and mobilized to trace and map the current locations of the nomadic households at Temporary Nomadic Settlements around their rural village taking into account seasonal movements, security conditions, and access constraints.

Once mobilized, Nomadic Link-Workers play a critical facilitation role throughout the enumeration process. They escort listers and enumerators to the exact locations of nomadic households, often navigating remote and difficult terrain that would otherwise be inaccessible or time-consuming for

external survey teams. This accompaniment not only improves logistical efficiency but also enhances community trust and acceptance, as the presence of a known and trusted intermediary reduces suspicion and reluctance among nomadic households to participate in surveys.

An additional strength of the TNS approach is its efficiency in coverage. With the guidance of nomadic link-workers, the precise locations of selected nomadic households are known in advance; survey teams can plan field movements more effectively, minimizing missed households and reducing repeated visits. This targeted approach saves both time and resources, which is particularly critical in contexts characterized by limited funding, difficult terrain, and security challenges. Furthermore, by reducing reliance on indirect aggregation points, the TNS approach mitigates systematic exclusion of households that do not visit water points, markets, or communal gathering sites.

Overall, the Temporary Nomadic Settlement approach, supported by Nomadic Link-Workers, offers a pragmatic and scalable solution for enumerating nomadic populations. By grounding data collection in actual settlement locations and leveraging local knowledge networks, it enhances coverage, accuracy, and operational efficiency, making it a valuable methodological option for censuses, household surveys, and rapid assessments targeting mobile pastoral communities.

4. The Seasonal Effect

The seasonal mobility of the Somali nomadic population is strongly shaped by environmental conditions, particularly the availability of pasture and water. During the dry season, areas surrounding rural villages often become heavily overgrazed due to prolonged use by both livestock and nearby communities. As a result, nomadic pastoralists are compelled to leave their temporary settlements near these villages and migrate to more remote and less exploited areas where pasture is still available. These movements are often long-distance and take nomads into sparsely populated and hard-to-reach areas, making their locations unpredictable and difficult to access. This seasonal dispersion has important implications, especially for data collection and service delivery, as they become highly scattered, reducing their visibility and accessibility. Enumerators and service providers face significant challenges in locating and reaching them, as they are no longer concentrated in identifiable settlements [12], [13].

In contrast, the onset of the rainy season brings a reversal of this pattern. With the regeneration of pasture and improved water availability near rural villages, nomadic groups gradually return to where they used to be. They re-establish temporary camps closer to settled communities, often in locations they had previously occupied. During this period, livestock productivity improves, leading to increased availability of milk and other dairy products. Nomadic households commonly engage in small-scale trade, selling these products in nearby villages and markets.

This seasonal concentration during the rainy period creates a critical window of opportunity for enumeration and service provision. Since nomadic populations are more clustered, accessible, and engaged in economic interactions with settled communities, it becomes significantly easier to identify, approach, and include them in surveys, censuses, and development programs. Therefore, understanding these seasonal movement patterns is essential for planning effective data collection strategies and ensuring better coverage of nomadic populations. The figure below shows nomadic households that reside at Temporary Nomadic Settlements closer to the rural village at one district in one of the Somali regions.

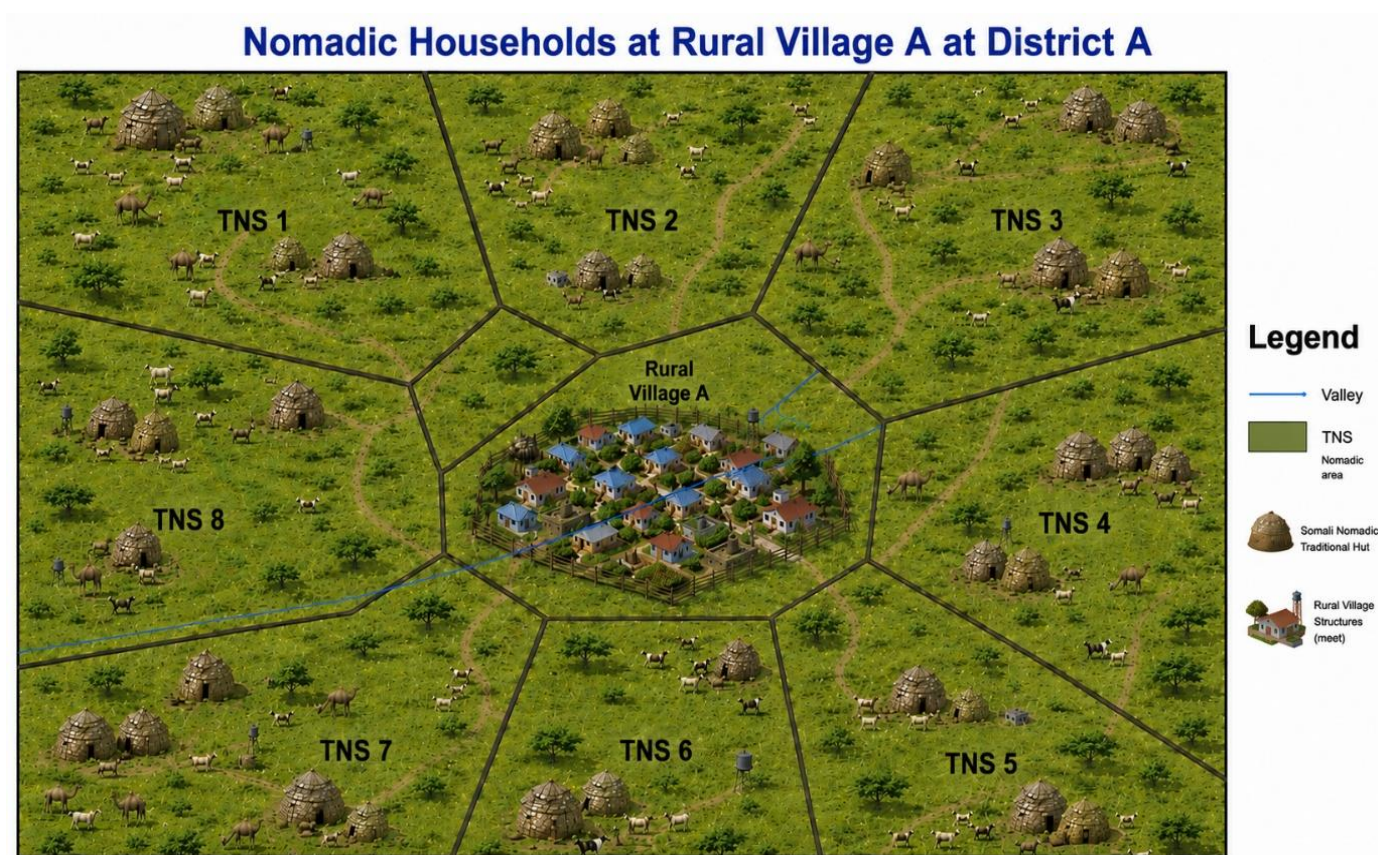


Figure 1. Temporary Nomadic Settlements at Rural Village A

5. Mitigation of the TNS Limitations

One significant limitation of the Temporary Nomadic Settlement (TNS) approach is the possibility that the target nomadic population may relocate outside the selected TNS, or move to the intersection of two neighboring TNS, before or during the data collection period. Consequently, some households initially included in the sampling frame may no longer be present at the time of enumeration, potentially resulting in under coverage and reduced representativeness of the survey estimates if appropriate mitigation measures are not implemented.

To minimize this limitation, a series of complementary strategies can be employed. First, the interval between the listing operation and the actual enumeration should be kept as short as possible to reduce the likelihood of significant population movement. Second, a network of trained Nomadic Link-workers residing in nearby rural villages should continuously monitor the movements of nomadic households and provide real-time updates to field teams regarding changes in settlement locations. Third, prior to the commencement of enumeration, a rapid verification exercise should be undertaken to confirm the continued existence and location of each selected TNS. Where households have moved to a nearby location, enumerators can be guided to the new settlement to complete the interviews, thereby preserving the original sample.

Furthermore, integrating Geographic Information System (GIS) technology, GPS coordinates, satellite imagery, and mobile communication with field teams can facilitate the rapid identification and tracking of relocated settlements. Daily communication between field supervisors, enumerators, and Nomadic Link-workers can further enhance the responsiveness of survey operations [14].

This approach enhances the timeliness and accuracy of data collection, as it allows for rapid adaptation of sampling efforts based on observed changes in population distribution.

Implementing these strategies can significantly improve the reliability and representativeness of the data collected, ultimately enhancing the effectiveness of research and interventions in pastoralist communities.

6. Operational Process

Operationally, the TNS approach is implemented in a phased, field-based manner to build and use the sampling frame. Here's an expanded breakdown:

Step 1: Identification and Listing of TNS

- Survey teams guided by nomadic link-workers (e.g., enumerators from research organizations, non-governmental organizations (NGOs), or government agencies) work district by district to compile a comprehensive list of all Temporary Nomadic Settlements (TNS). A Temporary Nomadic Settlement (TNS) is defined as a temporary location where nomadic households reside for a short period, ranging from a few days to several months, before relocating to another area. Each TNS is assigned a unique name or, where no local name exists, is identified by the name of the nearest rural village and its GPS coordinates is taken. The key advantage of the Temporary Nomadic Settlement (TNS) approach is that when a household leaves one TNS, it typically relocates to another TNS associated with a different rural village rather than disappearing from the settlement network.
- Identification relies on a combination of methods: satellite imagery for initial scouting for verification, local informants, mobile patrols, or even using drone if possible in remote areas. The goal is exhaustiveness—aiming to cover 100% of known or suspected TNS in the district to minimize omission bias.
- Nomadic Link-Workers play a crucial role here. These are trusted individuals from the nomadic community (e.g., elders, translators, or trained locals) who help locate hidden or hard-to-reach settlements. They ensure cultural sensitivity and build rapport, reducing refusal rates.

Step 2: Data Collection for Each TNS

For every identified TNS, the team records key details with assistance from Link-Workers:

- Number of Households: A count of family units or tents/dwellings. This provides a basic measure of settlement size and helps in probability-based sampling (e.g., larger settlements might have a higher chance of selection).
- Basic Settlement Characteristics: This could include qualitative or categorical data like primary livelihood (e.g., herding, trading), water access, sanitation facilities, proximity to roads, or environmental features (e.g., near a river or grazing land). These help contextualize the settlement and stratify the sample if needed.
- Approximate Duration of Stay: An estimate (e.g., "2 weeks" or "1-3 months") based on discussions with residents. This captures the "temporary" nature and allows for timing follow-up surveys before the group moves.
- Data is collected via mobile apps, tablets, or paper forms for efficiency, often in real-time to account for rapid changes.

Step 3: Building the Dynamic Sampling Frame

- The compiled list becomes a sampling frame—a structured database or spreadsheet from which households are randomly or systematically selected for interviews.
- Dynamic and Locally Validated: Unlike fixed frames (e.g., a 5-year-old census list), this one is updated on-the-fly during data collection. Local validation (e.g., cross-checks with community leaders) ensures accuracy and buy-in, reducing errors from outdated information.

- Households are then selected from this frame using probabilistic methods (e.g., simple random sampling or stratified sampling based on settlement size). For example, if a TNS has 50 households, you might randomly select 10 for interviews.

Step 4: Implementation and Iteration

- Interviews proceed immediately after selection to capture the population before they disperse.
- The sampling frame can be updated iteratively throughout the survey to reflect changes in the spatial distribution of Temporary Nomadic Settlements (TNS). For example, if a very large TNS is subdivided into two or more smaller settlements during the survey period, the newly formed TNS can be incorporated into the sampling frame through a controlled updating process. This adaptive approach ensures that the frame remains current and accurately represents the dynamic and fluid spatial distribution of nomadic populations. Consequently, it improves coverage, minimizes the risk of under- or over-enumeration, and enhances the overall quality and reliability of census or survey estimates.
- This process typically requires coordination with local authorities, ethical approvals (e.g., informed consent), and logistics like vehicles for remote access.

Benefits Over Traditional Fixed Sampling Frames

- Improved Representativeness:** Fixed frames often exclude nomads entirely or misrepresent them by assuming static locations. The TNS frame mirrors real-time movements, reducing bias and increasing the validity of survey results (e.g., for estimating poverty rates or health needs).
- Timeliness and Flexibility:** It accounts for seasonality (e.g., wet vs. dry seasons) and unpredictability, making data more actionable for policy or aid distribution.
- Community Engagement:** Involving Link-Workers fosters trust, improves data quality, and can empower nomadic communities by giving them a voice in the process.
- Cost-Effectiveness:** While initial fieldwork is intensive, it avoids the waste of resources on outdated lists, potentially lowering overall survey costs in dynamic environments.
- Scalability:** Can be adapted to various scales (e.g., national surveys or targeted studies) and integrated with tech like GIS for mapping.

Potential Risks and Mitigations

While effective, the Temporary Nomadic Settlements (TNS) approach isn't without hurdles: the table below details the possible Risks and Mitigations.

Table 1. Risks and Mitigations

	Risks	Mitigation
1	Remote or insecure areas may hinder access.	Use satellite phones, security escorts, or phased rollouts.
2	Data Volatility: Settlements can dissolve quickly.	Shorten the time between listing and interviewing.
3	Bias Risks: Over-reliance on Link-Workers could introduce favoritism.	Train and rotate workers, with independent verification
4	Resource Intensity: Requires skilled teams and funding.	Partner with NGOs or use digital tools for efficiency
5	Ethical Considerations	Ensure privacy (e.g., anonymize GPS data) and avoid disrupting nomadic lifestyles.

Table 2. TNS Sample Frame

REG_NAME	REG_CODE	DIST_NAME	DIST_CODE	NAME OF SETTLEMENT or VILLAGE	TNS Name	LINKWORKER'S FULL NAME	LINKWORKER'S PHONE NUMBER	LEVEL OF POPULATION	GPS
Region A	17	District A	1701	Village A	TNS1	Mr. A	1700	Medium	

REG_NAME	REG_CODE	DIST_NAME	DIST_CODE	NAME OF SETTLEMENT or VILLAGE	TNS Name	LINKWORKER'S FULL NAME	LINKWORKER'S PHONE NUMBER	LEVEL OF POPULATION	GPS
Region B	18	District B	1701	Village B	TNS2	Mr. B	3303	High	
Region C	19	District C	1701	Village C	TNS3	Mr. C	1774	Low	

Variables Contained in the Sampling Frame

The sampling frame is essentially a database with the following variables (as per your description). Each element has been expanded upon with an explanation of its intended purpose, associated data type, and possible uses;

Reg_name (Region Name): The full name of the administrative region (e.g., "Sahel Region"). Purpose: For geographic stratification and aggregation of results at a regional level. Data Type: Text string.

- **Reg_Code (Region Code):** A unique identifier (e.g., "SAH-01"). Purpose: Enables easy linking to other datasets (e.g., national statistics). Data Type: Alphanumeric code.
- **Dist_Name (District Name):** The name of the district within the region (e.g., "District X"). Purpose: Provides finer geographic detail for localized analysis. Data Type: Text string.
- **Dist_Code (District Code):** A unique code for the district (e.g., "DX-001"). Purpose: Facilitates data merging and mapping. Data Type: Alphanumeric code.
- **Name Of Settlement Or Village:** The local name of the rural Village (e.g., "village 1, 2" or a traditional name). Purpose: Identifies specific sites for follow-up or verification. Data Type: Text string; may include aliases if fluid.
- **TNS_Name:** The name of Temporary nomadic Settlement (e.g., TNS1, TNS2.). Purpose: Identifies specific location of the nomadic household, Data Type: Text string
- **Linkworker's Full Name:** The full name of the Nomadic Link-Worker assigned (e.g., "Mr. Ahmed Farah"). Purpose: Accountability and contact for validation or issues. Data Type: Text string.
- **Linkworker's Phone Number:** Contact number (e.g., "+252-656-7890"). Purpose: Enables quick communication for updates or clarifications. Data Type: Numeric string; include international codes for mobility.
- **Level of Population:** Likely the estimated population size or number of individuals (e.g., "150 people"). Purpose: Complements household counts for sampling weights or density analysis. (Note: This seems related to "number of households" but focuses on total people; clarify if it's households vs. individuals.) Data Type: Numeric (integer).
- **GPS Coordinates:** Latitude and longitude (e.g., "21.0583° N, 45.7374° E"). Purpose: Precise location tracking for mapping, spatial analysis, or revisits. Can be used in GIS software to visualize nomadic patterns. Data Type: Numeric pairs; ensure accuracy via devices like smartphones.

These variables form a robust, minimal dataset that's easy to maintain and expand (e.g., adding variables like "Date of Listing" for temporal tracking).

The TNS approach represents a pragmatic evolution in survey methodology for hard-to-reach populations, emphasizing adaptability over rigidity. If implemented well, it can yield high-quality data for evidence-based decisions in development, humanitarian aid, or research.

7. Survey Designs

Two-Stage Sampling of Nomadic Households Using Temporary Nomadic Settlements (TNS)

Sampling nomadic households requires adapting conventional probability sampling methods to account for high mobility, dispersed settlements, and insecurity. A commonly applied approach is a two-stage cluster sampling design, where Temporary Nomadic Settlements (TNS) serve as the primary sampling units (PSUs) [15].

In the first stage, Temporary Nomadic Settlements are identified and defined as PSUs. A TNS refers to a temporary aggregation of nomadic households around shared resources such as water points, grazing areas, seasonal markets, or service delivery sites. These locations are mapped in advance through consultations with local authorities, clan elders, nomadic link-workers, and community informants. Where available, satellite imagery and previous survey listings (e.g., from earlier census or survey frames) are also used to validate settlement locations.

TNS are then selected using Probability Proportional to Size (PPS) sampling, where size is typically measured by the estimated number of households or shelters at each settlement. PPS ensures that larger nomadic settlements have a higher probability of selection while maintaining self-weighting of households at the final stage. This is critical for ensuring representativeness of nomadic populations that vary widely in size and density.

Second Stage: Micro-Listing and Household Selection;

Once a TNS is selected, a micro-listing exercise is conducted on the ground to create a complete and up-to-date list of all households currently present at that settlement. Due to the dynamic nature of nomadic populations, listing is carried out immediately prior to data collection to minimize coverage errors. Enumerators, often accompanied by trained nomadic link-workers or local guides, systematically identify all eligible households within the TNS.

From the completed household list, a fixed number of households is selected using simple random sampling or systematic sampling. This second-stage selection ensures that every household within the selected TNS has a known and non-zero probability of inclusion in the survey.

Replacement and Contingency Protocols

Given the high levels of mobility and insecurity in nomadic areas, clear replacement protocols are established. If a selected TNS is inaccessible due to security constraints, environmental shocks, or population movement, it is replaced with a pre-identified reserve TNS from the same sampling stratum and with similar characteristics. Importantly, household-level substitution is avoided to preserve the probabilistic nature of the design. All replacements are fully documented to maintain transparency and data quality.

Ensuring Coverage and Representativeness

This adapted two-stage sampling approach allows nomadic households—who are often excluded from conventional household surveys—to be adequately represented. By anchoring sampling to Temporary Nomadic Settlements and combining PPS selection with real-time household listing, the method captures both spatial concentration and mobility patterns. Such approaches have been operationalized in large-scale surveys, including the Somali Health and Demographic Survey, where standard sampling frameworks were modified to address the realities of nomadic and pastoralist populations.

Overall, the TNS-based two-stage sampling framework provides a statistically robust, operationally feasible, and context-appropriate method for enumerating nomadic populations, ensuring their inclusion in national demographic and health statistics.

Below is a clear, formal set of sampling probability and survey weighting formulas tailored exactly to your two-stage TNS-based sampling design for nomadic households. The notation is standard and suitable for methodology sections, survey reports, or academic papers.

Notation and Definitions

Let:

h = sampling stratum (if stratification is used in different Geographical areas)

i = Temporary Nomadic Settlement (TNS), $i = 1, 2, \dots, N_h$

j = household within TNS i

N_{hi} = estimated number of households in TNS i (measure of size, MOS)

$\sum_{i=1}^{N_h} N_{hi}$ = total households in stratum h

n_h = number of TNS selected in stratum h

M_{hi} = number of households listed during micro-listing in TNS i

m_{hi} = number of households sampled in TNS i

Stage 1: Selection of TNS (PSUs) Using PPS

TNS are selected with Probability Proportional to Size (PPS), where size is the estimated number of households.

Stage-1 Inclusion Probability of TNS i

$$\pi_{1hi} = \frac{n_h \times N_{hi}}{\sum_{i=1}^{N_h} N_{hi}}$$

Stage 2: Selection of Households Within TNS

After micro-listing, households are selected by Simple Random Sampling (SRS) or Systematic Sampling.

Stage-2 Inclusion Probability of Household j in TNS i

$$\pi_{2hij} = \frac{m_{hi}}{M_{hi}}$$

Every household present at the time of listing has an equal probability of selection within the TNS.

Overall Probability of Selection for Household j

The joint probability of selecting household j in TNS i is:

$$\pi_{hij} = \pi_{1hi} \times \pi_{2hij}$$

Substituting from above:

$$\pi_{hij} = \left(\frac{n_h \times N_{hi}}{\sum_{i=1}^{N_h} N_{hi}} \right) \times \left(\frac{m_{hi}}{M_{hi}} \right)$$

Base Sampling Weight (Design Weight)

The **base weight** is the inverse of the overall probability of selection:

$$w_{hij}^{(0)} = \frac{1}{\pi_{hij}}$$

$$w_{hij}^{(0)} = \frac{\sum_{i=1}^{N_h} N_{hi}}{n_h \times N_{hi}} \times \frac{M_{hi}}{m_{hi}}$$

Adjustment for Non-Response (If Applied)

If household-level non-response occurs within adjustment cells c :

RR_c = response rate in cell c

$$w_{hij}^{(1)} = \frac{w_{hij}^{(0)}}{RR_c}$$

Final Survey Weight (Optional Calibration)

Weights may be post-stratified or calibrated to known population totals (e.g., region, livelihood zone, sex, age group):

$$w_{hij}^{(final)} = w_{hij}^{(1)} \times g_h$$

where g_h is a calibration factor.

Declarations

Author contributions

The author contributed to the conception, methodological development, writing, and final approval of the manuscript.

Competing interests

The author declares no competing interests.

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Ethics approval

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