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Assessment of cookstove stacking in Northern Ghana using surveys and stove use monitors

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ABSTRACT

Biomass burning for home energy use is a major health and environmental concern. While transitioning to cleaner cooking technologies has the potential to generate significant health and environmental benefits, prior efforts to introduce improved cookstoves have encountered many hurdles. Here, we focus on the increased stove use hurdle; households tend to use improved stoves alongside their traditional stoves rather than replacing them entirely, a phenomenon called cookstove "stacking." This work provides a systematic, multi-method assessment of households' cooking behaviors and cookstove stacking in the context of a 200-home randomized cookstove intervention study in Northern Ghana. Two stoves were selected for the intervention, a locally made rocket stove (Gyapa) and the Philips HD4012 LS gasifier stove. There were four intervention groups: a control group, a group given two Gyapa stoves, a group given two Philips stoves, and a group given one of each. Two stoves were distributed to each home in an attempt to induce more substitution away from traditional stoves. Adoption and usage patterns were quantified using temperature loggers at a subset of homes, as well as quarterly surveying in all households. We find that using multiple stoves each day is common practice within each intervention group, and that the two groups given at least one Gyapa had the largest reductions in traditional stove use relative to the control group, though use of traditional stoves remained high in all groups.

Background

Motivation

2.8 billion people burn solid fuels for cooking (Bonjour et al., 2013) and the resulting air pollution is the third leading risk factor for the global burden of disease, contributing to 4 million premature deaths per year (Lim et al., 2012). The environmental impacts from this activity are substantial. In addition to contributing to regional deforestation and forest degradation (Chidumayo and Gumbo, 2013), residential combustion (including wood, agricultural waste, animal waste, and coal) contributes an estimated 32% of particulate black carbon, and 64% of particulate organic carbon to global non-open burning emissions (Bond et al., 2013).

To address these issues, cookstove distribution programs and studies to replace traditional cooking methods with cleaner, more efficient ones continue to grow in scope and magnitude. Measurement of cookstove adoption is critical in determining the feasibility and likelihood of success of these programs. There are many factors involved in the decision to adopt a new stove, among them income, education, availability of viable clean cookstoves, fuel availability, financing, location, and cultural norms (Barnes et al., 1993; Pine et al., 2011; Ruiz-Mercado et al., 2011; Jan, 2012; Jeuland and Pattanayak, 2012; Lewis and Pattanayak, 2012; Rehfuess et al., 2013; Malla and Timilsina, 2014). Previous studies have found evidence that even when intervention cookstoves are used regularly, households often maintain regular use of their traditional stoves, a practice known as stove stacking (Pillarisetti et al., 2014; Stanistreet et al., 2015).

Research on Emissions, Air quality, Climate, and Cooking Technologies in Northern Ghana (REACCTING) (Dickinson et al., 2015) is a 200-home cookstove intervention study in the Kassena-Nankana (K-N) Districts of Northern Ghana, designed to learn about cooking

Abbreviations: RMM algorithm, Ruiz-Mercado Mukhopadhyay algorithm.
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behaviors and their impacts in this region. Past personal air pollution exposure studies in Ghana have measured worryingly high levels of CO (Burwen and Levine, 2012) and PM (Arku et al., 2008; Rooney et al., 2012; Van Vliet et al., 2013) due to cooking and other combustion sources. The ecological motivation is also strong, as the study is located within a climatically sensitive region at high risk of drought and forced migration (Warner, 2009; Antwi-Agyei et al., 2012). Ghana as a whole is experiencing alarming deforestation rates, with 33.7% of forest area (2.5E6 ha) lost since 1990, and a 2.19% annual deforestation rate from 2005 to 2010 (FAO, 2010). The Upper East region, encompassing our study area, is almost entirely categorized as a high-risk region for desertification (Adanu et al., 2013). Assessment of adoption and stacking has not been undertaken in this region of Africa, where the mix of remoteness and indoor/outdoor cooking offers new challenges.

Measuring Stove Use

In REACCTING, we determine the extent of stove use and stove stacking using two methods, stove usage monitoring with temperature data loggers (here referred to as stove usage monitors, or SUMs), and quantitative surveying. Both types of data have strengths and limitations. Stove usage monitoring allows identification of cooking events from extended time series of stove temperature (Ruiz-Mercado et al., 2012; Mukhopadhyay et al., 2012; Graham et al., 2014). SUMs have the advantage of eliminating the biases associated with self-reporting that have been observed in some studies (Thomas et al., 2013; Wilson et al., 2015). However, other sources of bias and measurement error are still possible with SUMs, including reactivity effects (higher use due to the knowledge of being monitored – see Thomas et al., 2016). Considerable uncertainty also remains in detecting cooking events using SUMs data, particularly for the traditional 3-stone fires (TSFs). In addition, SUMs data collection is costly. As a result, we were only able to collect SUMs data for a subset of study households rather than the entire sample. Meanwhile, surveys were conducted in all households at multiple discrete time points (quarterly), and provide us with detailed contextual information along with (potentially mis-reported) stove use information. Survey information such as foods cooked and fuel types used with each stove shed light on how and why certain stoves are being used by different households. Used in combination, survey and SUMs data can more effectively inform future cookstove and fuel improvement efforts in the region.

Our study makes an important contribution to the literature by examining cooking behaviors in a region that has received relatively little attention: Northern Ghana. In addition, this work is among the first to publish results on the use of *multiple* intervention stoves alongside traditional stoves. Previously, Loo et al. (2016) performed a study in Kenya assessing user perspectives on six different improved combustion stoves (ICSs) rotated through homes for two-week periods.

Methods

Study population and design

The REACCTING study ran from November 2013 to January 2016. The study population consisted of households in the K-N Districts that 1) were classified as rural, 2) used biofuels as their main cooking fuel source, 3) had at least one woman of childbearing age (18–55) and one child under five, 4) used a borehole as their primary water source, and 5) did not have electricity in the home. Using data from the district-wide Health and Demographic Surveillance Survey (HDSS) (Oduro et al. 2012), we identified the sample frame of households that met these eligibility criteria, and then used a cluster random sampling method to select 200 households for inclusion in the study. Detailed information on study design and sample selection is presented in Dickinson et al. (2015).

A baseline survey conducted in all 200 households prior to the stove intervention provided detailed information about local cooking practices that confirmed observations the study team made during the 2 years prior to the start of the study, and which informed the design of the REACCTING intervention. Even before the introduction of any new stoves, households in this area were cooking with multiple stoves, and with a mix of cooking technologies (Fig. 1). The most common cooking technology in this area is a traditional wood-fired 3-stone stove, but the majority of households (70%) owned at least one charcoal stove, locally known as a "coal pot," as well. Only 10% of households relied on a single stove to meet their cooking needs; 38% of households had two stoves at baseline, and the remaining 53% had three or more stoves.

Further, we observed that local cooking practices link stove and fuel types to specific foods. The dishes that are commonly prepared and eaten in this area determine households' stove needs; these staple dishes and associated cooking methods are listed in Table 1. The items

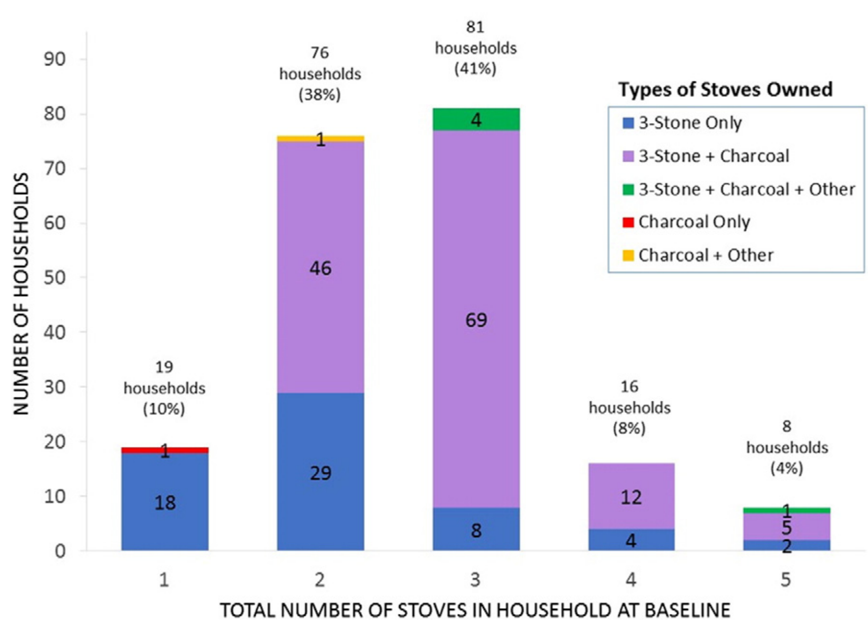

Fig. 1. Baseline (pre-intervention) cookstove technology mix among study households.